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FISH AND WILDLIFE AS RELATED TO WATER QUALITY OF THE LAKE HURON BASIN

Fish and Wildlife Service
Washington, D.C.

June 1969

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UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Charles H. Meacham, Commissioner

MARCH 3, 1849

FISH AND WILDLIFE AS RELATED TO WATER QUALITY OF THE LAKE HURON BASIN

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A DETAILED REPORT ON FISH AND WILDLIFE RESOURCES

148

UNITED STATES DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

FISH AND WILDLIFE AS RELATED TO WATER QUALITY
OF THE
LAKE HURON BASIN

A Special Report on
Fish and Wildlife Resources

June 1969

REPORT OF THE REGIONAL DIRECTORS

Bureau of Commercial Fisheries

Bureau of Sport Fisheries and Wildlife

UNITED STATES
DEPARTMENT OF THE INTERIOR
U. S. Fish and Wildlife Service

Mr. H. W. Poston, Regional Director
Federal Water Pollution Control Administration
U. S. Department of the Interior
33 East Congress Parkway, Room 410
Chicago, Illinois 60605

Dear Mr. Poston:

→ The report concerns → p. 4

This is a report on the effects of water quality upon the fish and wildlife resources of the Lake Huron Basin. It has been prepared under the authority and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and is in response to your request for our participation in the Great Lakes-Illinois River Basin Comprehensive Study.

This letter summarizes briefly the findings of the Bureau of Sport Fisheries and Wildlife and the Bureau of Commercial Fisheries. It is supported in detail by information included in the attached substantiating report.

Fish and wildlife resources and their habitats have been affected significantly in various areas by many changes, including the water quality in the Lake Huron Basin. The attached report describes these resources and habitats, the relationship of water quality to them, and discusses their role with respect to programs of water quality betterment.

Lake Huron is second in size among the five Great Lakes, with 23,010 square miles of water area and 72,620 square miles of drainage area. Nine thousand one hundred and ten square miles of the surface of Lake Huron is considered U. S. waters and 15,000 square miles of the lake's drainage is U. S. territory. Lake Huron averages 195 feet in depth, reaching a maximum of 750 feet. The entire U. S. shoreline lies within the State of Michigan. The most prominent feature of the shoreline is the "Thumb", which is formed by Saginaw Bay.

Fishery Resources

Lake Huron's sport fishery constitutes only a fraction of the lake's potential. Within the United States there are 5.8 million surface acres in the lake proper, plus many thousands of acres of inland lakes and streams in the watershed, which are valuable to the sport fishery. A wide variety of fish species, both warm-water and cold-water, inhabit these areas. The 1960 fishing pressure for the Lake Huron Basin is estimated at about 4.8 million angler days. With more efficient use of the lake and with increasing demand, annual angler-day use could approach 13.0 million by the year 2020.

Only a few species of fish have contributed substantially to the catch by Lake Huron's commercial fishermen. The total annual commercial catch averaged between seven and nine million pounds since 1955. Prior to that time, production was nearer 20 million pounds. Most of the commercial fishery products are consumed in areas outside of the basin. The projected demand for 2020 for fish from all of the Great Lakes is expected to increase fourfold over the total past annual 100 million pound production of the five lakes. Demands on the Lake Huron commercial fishery are expected to parallel the overall Great Lakes pattern.

Virtually 100 percent of Lake Huron Basin's commercial fisheries are carried out on Lake Huron. Saginaw Bay is by far the most productive area on the lake. While many tributaries are not fished commercially, they do supply spawning areas for important commercial and sport fish. Species composition and commercial production of Lake Huron remained relatively stable prior to the 1930's but have undergone major changes since stocks of lake trout, whitefish, and walleye have been reduced drastically, while carp, catfish, and alewives have increased in abundance. Presently, the alewife is the dominant species in the lake. The causes of these changes are not understood fully, but contributing factors include invasion by the sea lamprey and alewife, environmental deterioration in some areas, and overfishing of certain stocks. With the loss of high value species, there has been a shift in the commercial fishery to greater emphasis on carp, yellow perch, and chubs. The number of full-time fishermen has declined sharply.

Re-establishment of a balanced predator-prey relationship in Lake Huron is essential to achieve a stable and productive resource base. This will require full implementation of lamprey control and continued selective stocking of predator species. Careful monitoring of the fishery base will be necessary as these activities proceed in order to determine the nature of the changes that occur and to indicate possible adjustments which may be necessary in management procedures. The goal envisions a mutually supportive relationship between the sport and commercial fisheries leading to balanced utilization of the total fishery resource.

Wildlife Resources

The watershed of Lake Huron contains some of the best wildlife habitat in the Great Lakes Region. The heavily forested northern half of the watershed provides prime habitat for deer and small game. The Saginaw Bay area is an outstanding area for many kinds of wildlife, especially waterfowl. Farm game habitat previously produced excellent pheasant populations, particularly in the Michigan "Thumb" area. Unfortunately, the general decline of pheasant populations throughout the North Central United States is also of major concern in Michigan.

The 1960 hunting pressure in the Lake Huron Basin is estimated at approximately 3.3 million hunter days. Basin hunter use could increase to approximately 9.5 million annual days use by the year 2020 if an attractive habitat base is maintained.

Fish and Wildlife Aspects of Water Quality Planning

A large share of the economic and recreational values of the Lake Huron Basin depends directly upon the lake, its bays, and inshore waters. Fish and wildlife depend vitally upon high quality water which meets the various biological requirements for feeding, growth, reproduction, and survival.

Except for inner Saginaw Bay and certain other inshore areas, Lake Huron has not exhibited the obvious signs of water quality degradation apparent in Lakes Michigan and Erie. Probably water quality changes to date have not proceeded to a point resulting in significant adverse effects on fish and aquatic life resources. Although water quality is relatively high from the standpoint of fish and wildlife, some indications of change have developed. In the open lake, there has been a slight but real increase in total dissolved solids. Dissolved oxygen while usually near saturation, has been reported as low as 66 percent of saturation in Saginaw Bay. Were it not for the relatively rapid flushing rate of the bay, more serious oxygen depletion problems might have already developed. Some nuisance growths of cladophora have occurred in certain inshore areas and oligochaetes, often a biological indicator of enriched or polluted habitat, are dominant in the vicinity of several harbors. These indications of changing water quality should be taken seriously in spite of their limited scope and steps taken to slow down, and eventually halt, inputs of pollution into the lake. The assessment of overall high quality for Lake Huron waters does not apply to many tributary streams such as the Saginaw River where extensive deterioration of water quality has taken place.

Although it will be important to exercise strict control over pollutants entering Lake Huron from its own basin, the overriding determinant of Lake Huron water quality will continue to be the quality of waters received from Lakes Michigan and Superior. With the exception of bacteriological counts, we believe that adherence to water quality standards capable of meeting fish and wildlife needs will automatically meet the needs of most other uses. With the largely unspoiled resource represented by Lake Huron and its basin, it is in the public interest to preserve and enhance this important area.

As a result of the 1965 Water Quality Act, Michigan has developed water quality standards to protect the fish and wildlife resources of Lake Huron. Under provisions of the Act, the Secretary of Interior has approved all but the temperature standard proposed by Michigan and it is anticipated that agreement will soon be met.

A great deal has yet to be learned about adequate aquatic life criteria. Additional research may demonstrate the need for re-definition and refinement of the standards to meet fish and wildlife requirements. Moreover, it must be recognized that water quality standards are the minimum necessary to maintain various conditions of habitat quality. In view of the rapid changes occurring in the Great Lakes ecosystem, every effort should be made to maintain the quality of those areas currently exceeding these minimum standards. It is apparent that existing water quality over most of the Lake Huron Basin is better than called for by the standards, for most if not all parameters. Until careful research demonstrates beyond a reasonable doubt that degradation of existing water quality to the level of the standards will not result in harmful effects upon fish and aquatic life resources, it is the position of the Fish and Wildlife Service that the goal of pollution abatement in Lake Huron should be retention of the existing overall high quality of its waters. This will require improving conditions in certain local areas such as the Saginaw River and inner Saginaw Bay which are significant sources of pollution input. It will also depend heavily on present and future efforts to stop the accelerated enrichment and addition of other pollutants into Lake Michigan. Programs to maintain the present water quality in the open waters of Lake Huron are meaningless unless the water flow from Lake Michigan is prevented from further deterioration.

Because of their inherent sensitivity to subtle, long-range environmental changes, fish and aquatic organisms make excellent indicators of such changes, thus enabling problems to be recognized and steps taken towards their solution before they become critical in human affairs. This has not been recognized sufficiently in the past. A change of emphasis is called for in the future including acceleration of necessary research and monitoring in the fish and wildlife-aquatic organism sector of water quality.

To obtain maximum benefits from an environmental research program and to assure continuity in data collection, there must be adequate coordination and exchange of information. Because fishery agencies have a broad responsibility to maintain harvestable surpluses in existing populations of aquatic life and to contribute to man's understanding and control of aquatic living resources and their environment, it seems logical that these agencies should also have a major role in coordinating and conducting research related to long-term water quality changes. Without proposing any specific institutional arrangements, this function may be exercised in part through such established mechanisms as the Great Lakes Fishery Commission, where an ecosystem approach encompassing all of the Great Lakes can be adopted.

Recommendations

On the basis of the foregoing considerations, it is recommended that:

1. The Federal Water Pollution Control Administration's water pollution control plan for the Lake Huron Basin be implemented as a first step, recognizing that it may not be sufficient in its present form to solve all fish and wildlife-related water quality problems.

2. Research programs be expanded to develop improved methods of treating wastes in major problem areas, with sufficient coordination maintained with fish and wildlife interests to insure proper consideration of fish and wildlife needs.

3. Local, State, and Federal pollution laws and enforcement programs be reviewed and revised periodically, in accordance with improved techniques and changing fish and wildlife water quality standards.

4. A permanent water quality monitoring system be established which recognizes fish and wildlife needs and which will include all areas of recognized importance to fish and wildlife. It is further recommended that Federal Water Pollution Control Administration administer this program with appropriate assistance from fish and wildlife conservation agencies.

5. Increased emphasis be placed on research and operations aimed toward control of agricultural pollution, including such sources as pesticides, herbicides, fertilizers, siltation, and streambank erosion.

6. Acquisition of despoiled wetland areas with high potential for development be accelerated by State and local conservation interests for eventual rehabilitation and restoration for fish and wildlife management purposes.

7. Because of the special relationship of fish, wildlife, and aquatic organisms to long-term changes in water quality and the responsibility of fishery agencies to increasing man's control of aquatic living resources and their environment, research on long-range environmental changes be conducted by these agencies and coordinated through established institutions such as the Great Lakes Fishery Commission, with the help and cooperation of private and educational groups.

The above recommendations are intended to conserve and develop existing resources. We recognize that implementation of these recommendations will require the strong support and active cooperation of numerous Federal and State agencies. In addition to your agency, these include the Michigan Department of Natural Resources as well as local agencies, private industry, and the citizenry in general. The services of the Fish and Wildlife Service remain available to assist in this important effort in any way possible.

Sincerely yours,

RW Burwell

R. W. Burwell, Regional Director
Bureau of Sport Fisheries and Wildlife

W F. Carbine

W. F. Carbine, Regional Director
Bureau of Commercial Fisheries

SUBSTANTIATING REPORT

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PREFACE

This study is authorized under the Federal Water Polution Control Act, Section 3(a) PL 660, as amended, which requires that a water pollution control plan be developed for each of six drainage basins (Illinois River, Lake Michigan, Lake Erie, Lake Huron, Lake Ontario, and Lake Superior).

Authority for participation by fishery interests in such studies originates in a Congressional Act of March 3, 1887 (16 U.S.C. 744) which authorized the Commissioner, U. S. Fish Commission, to prosecute investigations and inquiries concerning the supply of food fishes of the coasts and lakes of the United States and the determination of protective, prohibitory, or precautionary measures to be adopted. Subsequent legislation, particularly the Fish and Wildlife Act of 1956, as amended, and the Fish and Wildlife Coordination Act, refined and strengthened fish and wildlife responsibilities.

Section 5 of the Fish and Wildlife Coordination Act authorizes the Secretary of the Interior, through the Fish and Wildlife Service and the Bureau of Mines to make such investigations as he deems necessary to determine the effects of domestic sewage, mine, petroleum and industrial wastes; erosion silt, and other polluting substances on wildlife, and to make reports to the Congress concerning such investigations and/or recommendations for alleviating dangerous and undesirable effects of such pollution. These investigations shall include (1) the determination of standards of water quality for the maintenance of wildlife; (2) the study of methods of abating and preventing pollution, including methods for the recovery of useful or marketable products and by-products of wastes; and (3) the collation and distribution of data on the progress and results of such investigations for the use of Federal, State, municipal and private agencies, and individuals, organizations, or enterprises.

In keeping with these authorities, this report has been prepared by the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife.

The analyses in this report are based on statistical records, field investigations, published material, and the experience and judgment of a staff that has worked with the resource for many years. While far from complete for a resource base as large and complex as the Lake Huron Basin, this background is considered sufficient for indicating the dimensions of the resource and for making reasoned judgments on trends, problems, and future requirements. A list of references is attached to facilitate more detailed inquiry and, where appropriate, the text has been annotated selectively.

ACKNOWLEDGEMENTS

The published studies and surveys used in preparing this report are credited in the list of references. In addition, the encouragement, interest, basic data, ideas, and assistance contributed by the following agencies have helped greatly in preparing this report:

Federal Agencies

Bureau of Outdoor Recreation
Corps of Engineers
Federal Water Pollution Control Administration
Geological Survey
Public Health Service

Foreign Agency

Ontario Department of Lands and Forests

International Agency

Great Lakes Fishery Commission

State Agencies

Michigan Department of Natural Resources
Michigan Water Resources Commission

DESCRIPTION OF THE BASIN

A knowledge of environmental, or habitat factors is an essential part of any sound management program for Great Lakes' fish and wildlife. Closely allied to this discipline is the chief interest of this comprehensive report, water quality. Lake Huron is one of the least studied of the Great Lakes and relatively little is known concerning its habitat base. This section summarizes published information accumulated primarily since the early 1950's and data collected by the Bureau of Commercial Fisheries but not yet published.

THE GREAT LAKES

The five Great Lakes and their connecting waters have a combined surface area of over 95 thousand square miles and a total drainage area of 295,200 square miles (Table 1). They form the largest group of lakes in the world. The geographical area covered by this study, however, comprises only the United States portion of the Great Lakes and their watersheds, plus the Illinois River and its drainage basin. The latter basin adds another 30,000 square miles to the total drainage area. Figures 1 and 2 orient the reader to pertinent physical features of the Great Lakes basin.

LAKE HURON

Morphometry. In area, Lake Huron is the fifth largest lake in the world, and second largest of the St. Lawrence Great Lakes. It is estimated that the lake receives water at 48,000 cubic feet per second (cfs) from Lake Michigan via the Straits of Mackinac, and at 73,700 cfs from Lake Superior via the St. Marys River. Most water exits the lake at 177,900 cfs (average) through a single outlet, the St. Clair River. Both Lakes Huron and Michigan have the same elevation (580.54) feet above mean sea level), and, although sometimes the two are considered as one lake, they differ considerably in physico-chemical characteristics (Beeton and Chandler, 1963).

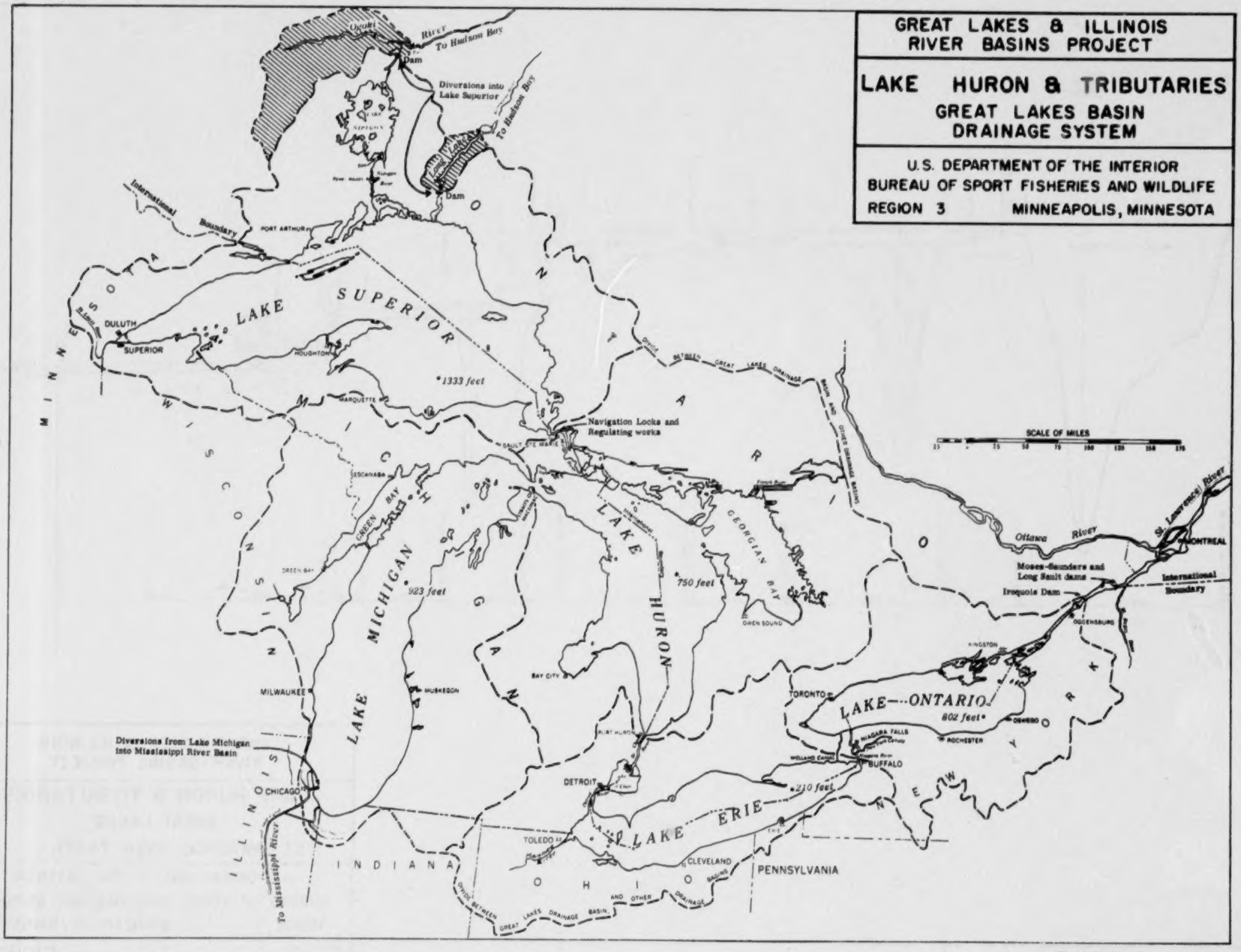
Lake Huron is 206 miles long, 183 miles wide, and occupies 32 percent (23,000 sq. mi.) of its 72,000 sq. mi. watershed (the lake included). This high proportion of lake area to total basin area is common to all of the Great Lakes, but unusual when smaller inland lakes are considered. Thus, Lake Huron and the other Great Lakes have relatively less area of watershed which can provide nutrients and pollutants from run-off. The volume of the lake is 850 cubic miles. To the north and northeast are North Channel and Georgian Bay, nearly isolated by a barrier formed by Bruce Peninsula, and Manitoulin and other islands. Depth in the bay is generally 100 to 300 feet. This area contains over 20,000 islands, and has a very irregular, wooded shoreline. Figure 3 shows depth contours for Lake Huron including Geogian Bay.

Bottom topography is generally irregular. The submerged valley of the ancient Stanley River is in the Straits region. (Stanley, 1938). Recent work has revealed a narrow, deep trough extending northwest along the length of the lower half of Georgian Bay (Anderson and Terasmae, 1966). A distinct submarine ridge extends across the lake proper from Alpena, Michigan, to Kincardine, Ontario. Immediately to the northeast is a fairly regular, broad, trough, and beyond that, a large area of ridges and valleys. The lake is deepest in this northeast basin. Southwest of the ridge is a broad, relatively smooth basin with depths to 300 feet. Saginaw Bay, a shallow (mostly 60 feet or less) arm 51 miles long, and 26 miles wide at the mouth, is the

Table 1. Physical Data of Great Lakes System 1/

Lake	Length (Mile)	Breadth (Mile)	Water area (sq. mi) U. S.	Water area (sq. mi) Canada	Total	Ave. surf. elev. since 1860 (ft.)	Maximum Depth (feet)	Mean Depth (feet)	Drainage area (sq. mi.)
Superior	350	160	20,700	11,120	31,820	602.20	1,333	487	80,000
Michigan	307	118	22,400	-	22,400	580.54	923	276	67,860
Huron	206	183	9,110	13,900	23,010	580.54	750	195	72,620
St. Clair	26	24	200	290	490	574.88	21	10	7,430
Erie	241	57	4,990	4,940	9,930	572.34	210	58	32,490
Ontario	193	53	3,600	3,920	7,520	246.03	802	283	34,800
Totals:			61,000	34,170	95,170				295,200

1/ Adapted from Beeton and Chandler "St. Lawrence Great Lakes" LIMNOLOGY IN NORTH AMERICA - University of Wisconsin Press - 1964.



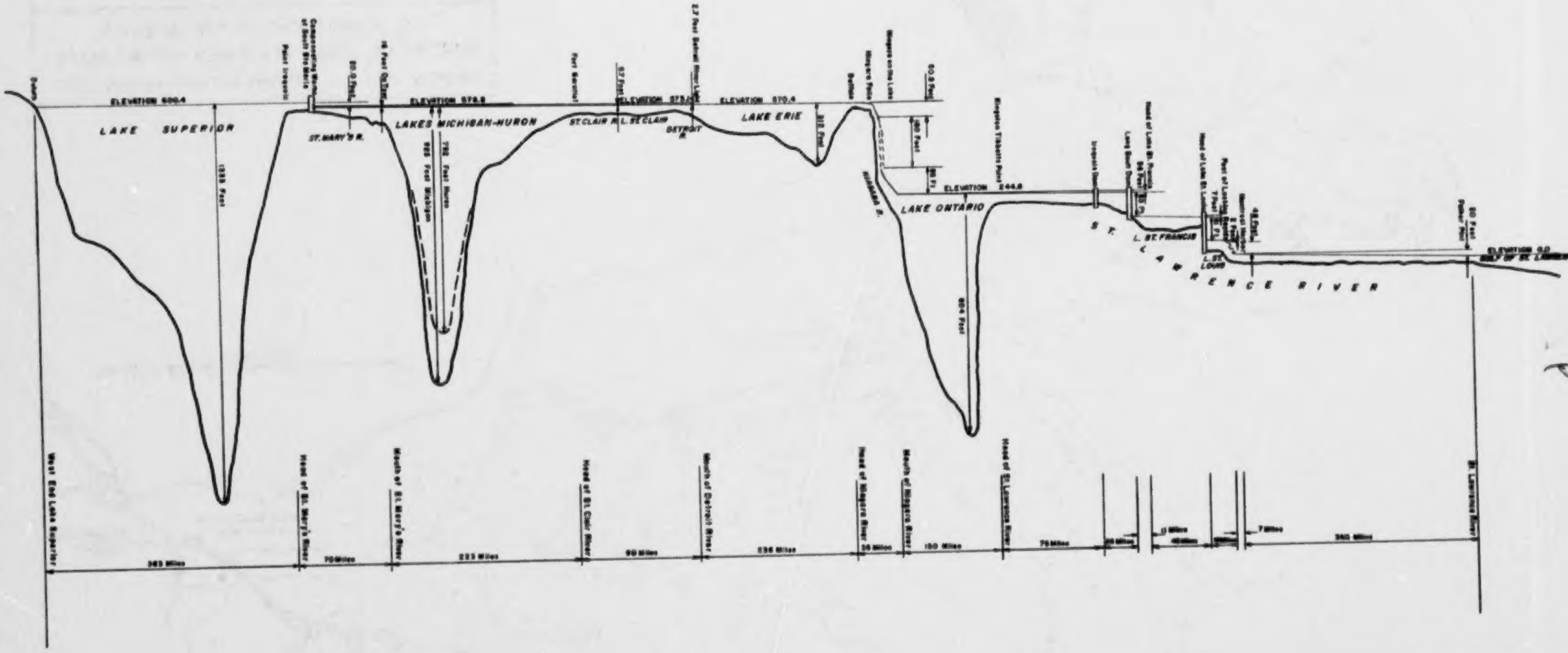
GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
GREAT LAKES BASIN
DRAINAGE SYSTEM

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

Ogoki River
To Hudson Bay
Dam
Diversions into Lake Superior
Long Lake
To Hudson Bay
Dam
Lake Nipigon
International Boundary
PORT ARTHUR
MINNESOTA
ONTARIO
DULUTH
SUPERIOR
LAKE SUPERIOR
HOUGHTON
1333 feet
MARQUETTE
Navigation Locks and Regulating works
SAULT STE MARIE
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
SCALE OF MILES
25 0 25 50 75 100 125 150 175
WISCONSIN
MICHIGAN
ESCANABA
GREEN BAY
GREEN BAY
LAKE MICHIGAN
923 feet
LAKE HURON
750 feet
GEORGIAN BAY
OWEN SOUND
French River
Ottawa River
St. Lawrence River
MONTREAL
Moses-Saunders and Long Sault dams
Iroquois Dam
International Boundary
OGDENSBURG
KINGSTON
MUSKEGON
BAY CITY
MILWAUKEE
TORONTO
LAKE ONTARIO
802 feet
OSWEGO
ROCHESTER
NIAGARA FALLS
WELLAND CANAL
BUFFALO
NEW YORK
Diversions from Lake Michigan into Mississippi River Basin
CHICAGO
ILLINOIS
To Mississippi River
PORT HURON
DETROIT
LAKE ERIE
210 feet
TOLEDO
CLEVELAND
INDIANA
OHIO
PENNSYLVANIA
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS

FIGURE 1


Duluth
ELEVATION 600.4
LAKE SUPERIOR
1333 Feet
Point Iroquois
Compensating Works of Sault Ste Marie
20.0 Feet
16 Feet
ST. MARY'S R.
ELEVATION 578.8
LAKES MICHIGAN-HURON
925 Feet Michigan
752 Feet Huron
Fort Gratiot
5.7 Feet
ELEVATION 573.2
ST. CLAIR R. L. ST. CLAIR
2.7 Feet Detroit River Light
DETROIT R.
ELEVATION 570.4
LAKE ERIE
210 Feet
Buffalo
Niagara Falls
Niagara on the Lake
50.0 Feet
160 Feet
NIAGARA R.
Kingston Tibbetts Point
ELEVATION 244.8
LAKE ONTARIO
804 Feet
Iroquois Dam
Long Sault Dam
Head of Lake St. Francis
84 Feet
ST. LAWRENCE RIVER
L. ST. FRANCIS
Head of Lake St. Louis
7 Feet
Foot of Lachine Rapids
L. ST. LOUIS
Montreal Harbor
48 Feet
Father Point
20 Feet
ELEVATION 0.0
GULF OF ST. LAWRENCE
West End Lake Superior
383 Miles
Head of St. Mary's River
70 Miles
Mouth of St. Mary's River
223 Miles
Head of St. Clair River
90 Miles
Mouth of Detroit River
236 Miles
Head of Niagara River
36 Miles
Mouth of Niagara River
180 Miles
Head of St. Lawrence River
75 Miles
13 Miles
7 Miles
380 Miles
St. Lawrence River

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

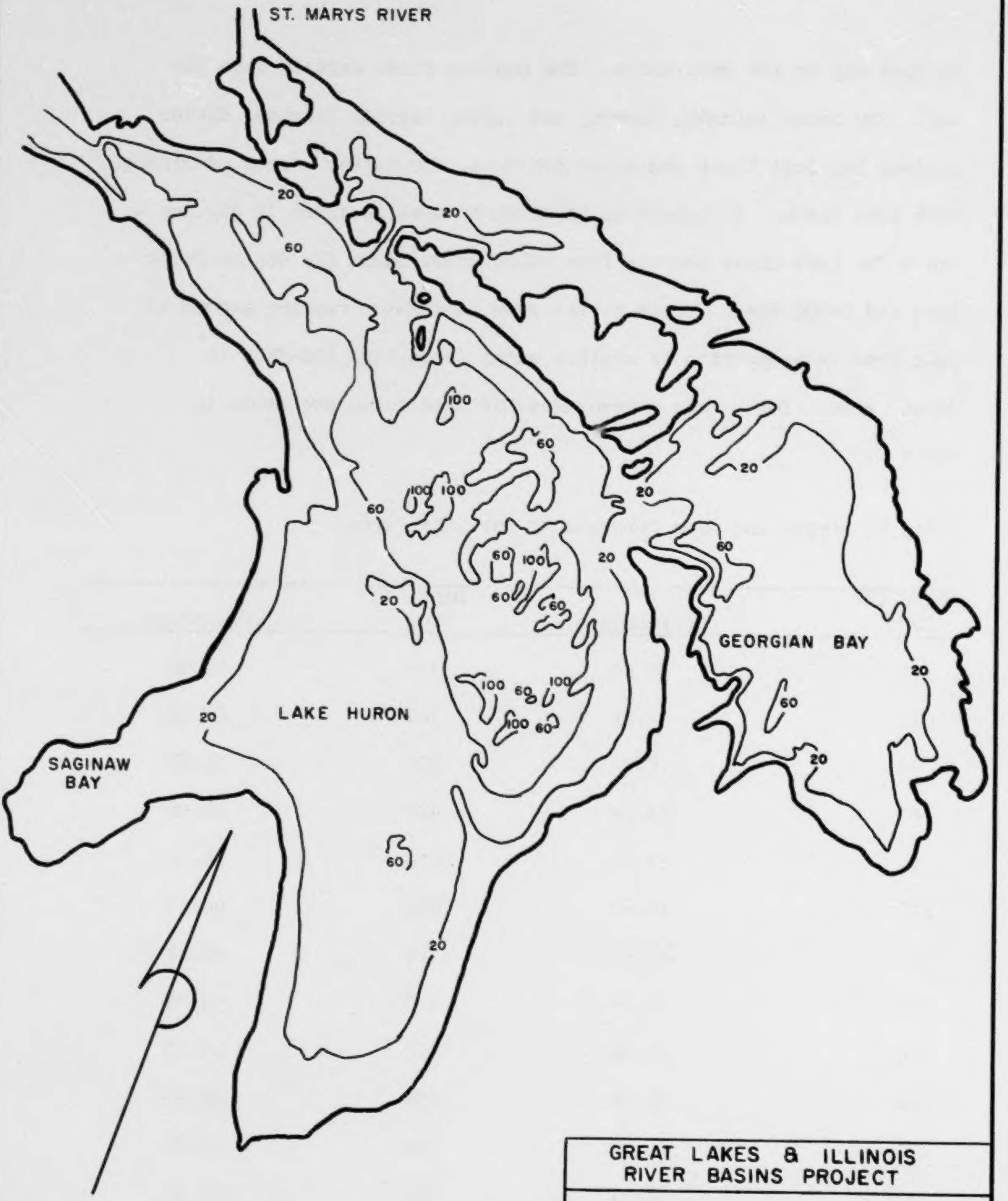
LAKE HURON & TRIBUTARIES

GREAT LAKES
ST. LAWRENCE RIVER PROFILE

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

E.M.P. 690313

FIGURE 2


ST. MARYS RIVER
20
20
60
100
60
100
100
60
20
60
100
60
60
20
60
20
GEORGIAN BAY
20
100
60
100
20
LAKE HURON
60
100
60
60
SAGINAW BAY
20
60
20

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
DEPTH CONTOURS (FATHOMS)

U.S. DEPARTMENT OF THE INTERIOR
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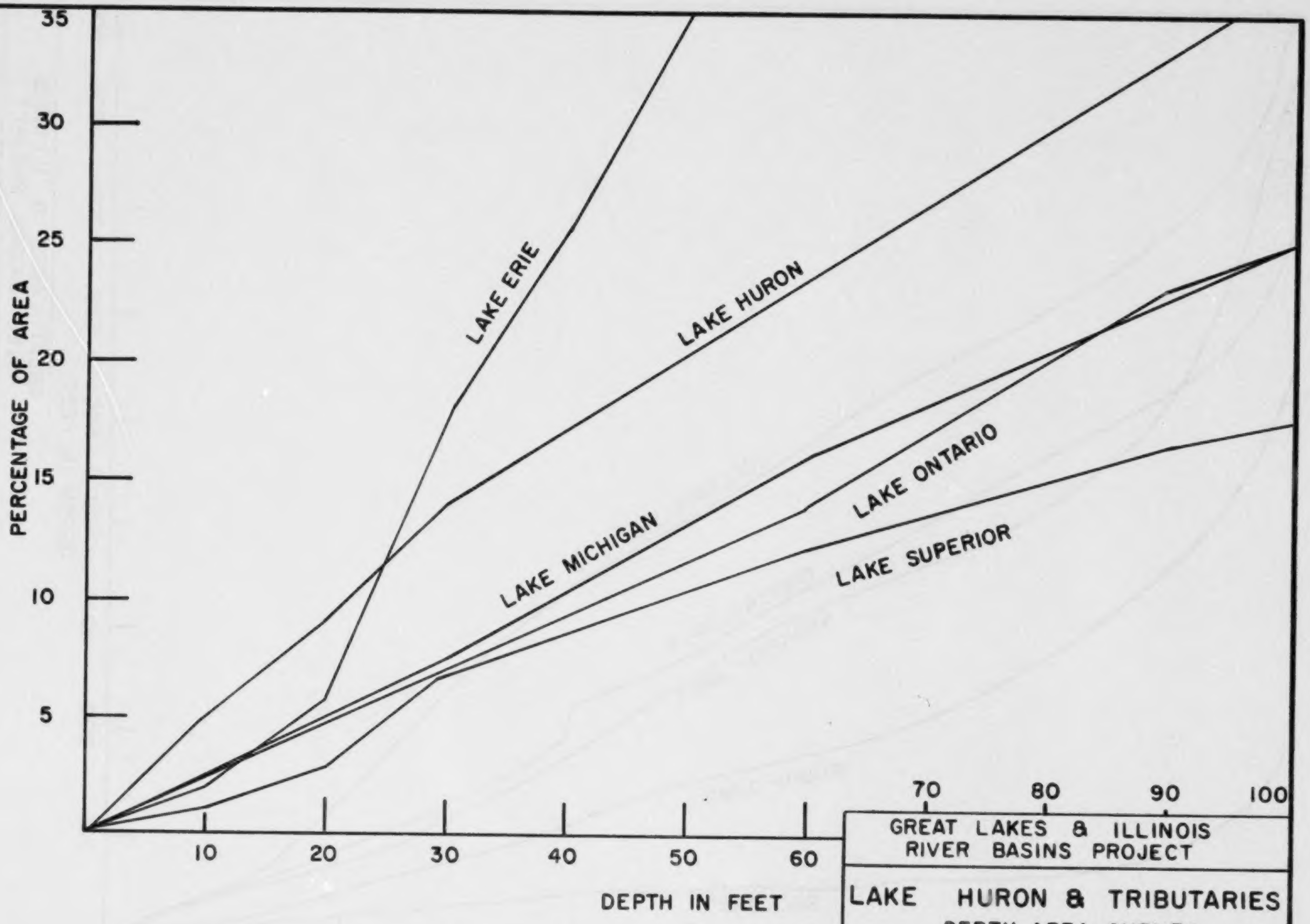
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 3

largest bay on the west shore. The Saginaw River empties into the bay. Two small islands, Charity and Little Charity Islands, divide Saginaw Bay into inner and outer portions, the latter a zone of mixing with Lake Huron. A comparison of depth to area is given in Figures 4 and 5 for Lake Huron and the four other Great Lakes for depths 0-100 feet and 0-900 feet. These curves show Lake Huron ranking second to Lake Erie in proportion of shallow water (less than 100 feet in depth) area. Depth-area percentages for Lake Huron are shown in Table 2.

Table 2. Depth and Area Percentages for Lake Huron

Depth in Feet	Percentage	Depth in Feet	Percentage
10	5.16	330	88.62
20	9.11	360	88.91
30	14.16	390	91.22
60	23.82	420	92.98
90	33.48	450	94.96
120	40.62	480	96.17
150	48.52	510	98.37
180	57.74	540	99.25
210	64.98	570	99.58
240	71.90	600	99.69
270	77.61	630	99.80
300	82.11	752	100.00

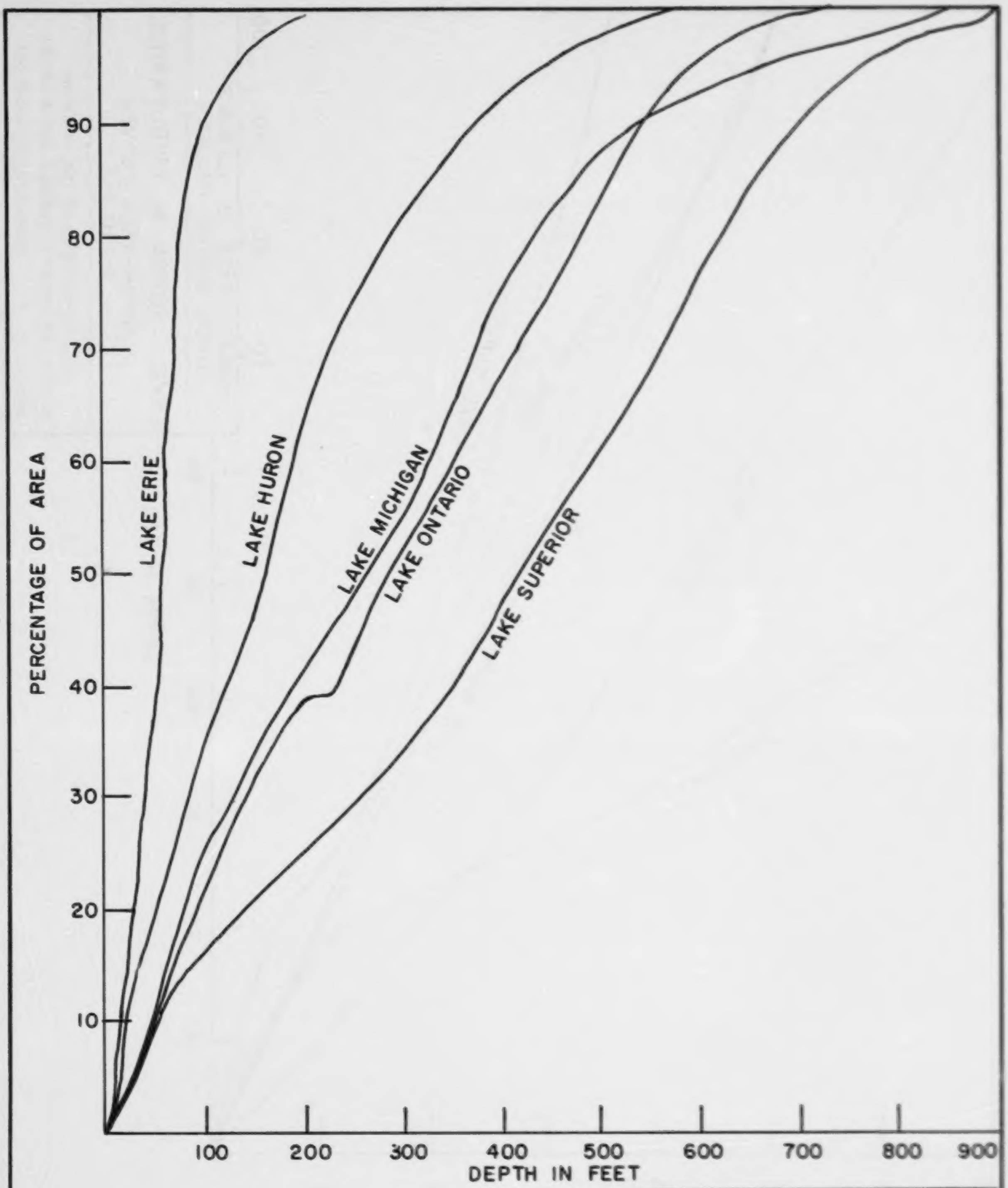


GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
DEPTH-AREA CURVES
0-100 FEET

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 4



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
DEPTH-AREA CURVES
0-900 FEET

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 5

Excluding the Georgian Bay-North Channel area, there are only two islands of substantial size, Mackinac and Bois Blanc Islands, both in the eastern edge of the Straits region. Lake Huron proper has a regular, wooded shoreline. The lake bottom is mostly clay, although sand and gravel occur at shallower depths and on beaches (Hough, 1958). Sand is the dominant sediment in the Straits of Mackinac, and silt deposits occur just to the east where lake volume slows incoming Lake Michigan water, reducing silt transport (Lauff, et al., 1961). In Saginaw Bay, large pebbles, coarse sand, and shell fragments are present in areas of strong currents; fine, gray to black silt and clay can be expected in slow-current areas; and medium to fine-grained sand is common throughout the bay (Wood, 1964).

Thermal Conditions. In general, Lake Huron undergoes the same annual temperature cycle observed in most other fresh-water lakes of the temperate zone. Specifically, the deep water remains near the temperature of maximum density (4°C or about 39°F) throughout the year, whereas surface and shallow waters undergo considerable thermal change through the seasons (Millar, 1952). In the spring, surface water gradually warms from 1°C (34°F) to 4°C until the lake proper is vertically homothermous. Shallow water may warm more rapidly, depending on local conditions. Temporary thermal stratification may occur in early June.

During July and August, a well-defined and persistent thermal stratification is established. The upper layer (epilimnion) is fairly homothermous (16°-20°C) and extends to a depth of 50 feet (Hachey, 1952). Water above 20°C (68°F) may occur, particularly near shorelines. The thermocline usually lies at a depth of 50 to 100 feet. In this layer, temperature decreases from 16° to approximately 7°C. The thermocline is present over all the open lake except at the extreme ends where inlet and outlet currents cause appreciable mixing.

A cooler, more turbulent atmosphere in the autumn creates considerable reduction in temperature of epilimnetic waters, resulting in a homothermous 4° water mass. Little data are available on autumn cooling in Lake Huron, but based on data from Lake Michigan, the following seems reasonable: epilimnetic water cools to 10°-13°C (50°-55°) by late October. Because of cooling and stronger winds, the thermocline is depressed as deep as 250 feet. Vertical mixing may cause a noticeable warming of deep water, probably the only time during the year in which warming occurs at those depths.

Cooling continues throughout the winter and into early spring. Ice generally begins forming in December and deteriorates in March. Open lake water may be homothermous (at about 3°C or 37°F) in March and April, while waters in shallower areas may be homothermous at less than 1°C. Solid ice sheets are mostly limited to sheltered areas such as bays, channels, among islands, and along shores. Ice in the open lake usually occurs as floes and does not inhibit mixing caused by wind.

Currents and Water Masses. On June 29, July 27, and August 25, 1954, synoptic surveys were conducted under the supervision of the Great

Lakes Research Division, University of Michigan, to determine patterns of circulation in Lake Huron (Ayers, et al., 1956). Two parent water masses, Lakes Michigan and Superior, and a mixture of the two, Lake Huron, were present. Lake Superior could be followed for only short distances horizontally or vertically. Lake Michigan and Lake Huron water were both widespread on the surface. At greater depths Lake Huron water was present on both sides of the lake, but Lake Michigan water was present only on the west side. Both masses were traceable into the southern end of the lake.

Surface water basically circulated counter-clockwise in the upper and central portions of the lake. Near the south end of the lake the surface water seemed to meander toward the outlet from the northeast. Data suggested that surface circulation is influenced by winds of the preceding 12 days. Little is known of subsurface currents in Lake Huron.

Although sinking and upwellings did occur during 1954, the thermocline was generally an effective barrier to complete vertical circulation. Some major sinkings did appear to penetrate the thermocline and buoy it up. Upwellings usually occurred near shore as a result of offshore winds pushing warm upper layers into the open lake.

During spring and fall, a thermal bar, or mixing zone between waters less than 4°C and waters greater than 4°C, constitutes a barrier to extensive offshore-onshore movement of water. The thermal bar, when it is close to shore in spring, probably limits movement of runoff

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In shallow Saginaw Bay, circulation is highly variable, depending both on local winds and the stronger Lake Huron circulation. However, the prevailing circulation is counter-clockwise; Lake Huron Water enters from the northeast and flows along the bay's north shore; the Saginaw River enters Lake Huron via the south shore of Saginaw Bay (Beeton, 1958; Johnson, 1958; Beeton, et al., 1967). Average flushing time of the bay is 186 days (Beeton, et al., 1967). Results of drift card studies in Georgian Bay suggest an upwelling on the west shore and west to east movement of surface water (Fry, 1956).

Light Penetration. Transparency (Secchi disc) readings during summer 1956, indicate the extent of mixing of Saginaw Bay and Lake Huron. In the bay, west of a line from Point Lookout to Charity Island to Oak Point, transparency ranged from 7 to 32 feet. In Lake Huron proper, readings ranged from 20 to 54 feet. Intermediate values occurred in the mouth of the bay and west to Charity Island, suggesting that this area is a mixing zone of lake and bay water (Beeton, 1958; Beeton, et al., 1967). Blue light (440-490 mu) penetrates the deepest into Lake Huron (Beeton, 1962).

Chemical Characteristics. Only a few studies have been completed on Lake Huron chemistry (e.g., Hough, 1958; Allen, 1964; Ayers, 1962). Lake Huron is primarily bicarbonate water (ca 100 ppm). Average pH is 8.1. Sulfate (9.7 ppm) is more concentrated than chloride (7.0 ppm). Average calcium, magnesium, sodium, silica, and potassium concentrations are 22.6, 6.3, 2.3, 2.3, and 1.0 ppm, respectively. Nitrate averages 400 ppb, and phosphorous, 10 ppb. Total dissolved solids are low, about 110 ppm, but more concentrated in Saginaw Bay than the open lake. In the open lake, dissolved oxygen is usually near saturation, even at the greatest depths, and super-saturation is common. Dissolved oxygen in Saginaw Bay is generally above 80 percent saturation but values as low as 66 percent have been reported (Beeton, et al., 1967).

Plankton. Little attention has been given the plankton of Lake Huron, and published studies of these important organisms are, for the most part, qualitative. The diatoms (Bacillariacceae) have been reported as the dominant plankters throughout the year (Davis, 1966). The most abundant forms of diatoms have been *Fragilaria*, *Tabellaria*, and *Cyclotella*. *Asterionella* is also common, but not as abundant as the other three genera. Zooplankton may, at times, equal the diatoms in biomass, although no quantitative information is available. Rotifers and protozoans, although apparently more numerous, probably compose less bulk than planktonic crustaceons. Of the latter, copepods seem dominant over cladocerans. *Diaptomus sicilis*, *D. ashlandi*, *D. minutis*, *D. oregonenis*, and *Senecella calanoides* are the more common forms in middle and upper layers of the lake (Robertson, 1966). *Limnocalanus macrurus* is probably an important deep water form.

Estimates of plankton abundance in Lake Huron have not yet been published. More quantitative information is needed since these organisms no doubt comprise the bulk of basic organic production. The Great

Lakes Institute, University of Toronto, has made extensive quantitative collections of zooplankton throughout Lake Huron. Preliminary analyses suggest that standing crop of zooplankters is greater in the southern half of the lake (Great Lakes Institute, 1964).

Benthic (Bottom) Organisms. Benthos in Lake Huron have been studied more intensively than plankton (Henson, 1966). Offshore, the benthic fauna are dominated by amphipods (Pontoporeia affinis) and mysids (Mysis relicta) which are very important in the forage base for fishes such as coregonids and sculpins. Although primarily benthic, individuals of both species often migrate at night to the lake surface, or at least, to the thermocline (Beeton, 1960). The amphipods may have a zone of maximum density near depths of 120 feet according to results of a study in South Bay (Cooper, 1962). Other important profundal forms numerically abundant are oligochaetes, sphaeriid clams (mostly Pisidium and Sphaerium), and midge-fly larvae (tendipedids), in that order (Teter, 1960).

Quality of benthic fauna changes in harbor and other inshore areas; oligochaetes, often a biological indicator or enriched or polluted habitat, are dominant both in bulk and numbers. Limnodrilus hoffmeisteri, a tubificid, is probably the most common, at least of the large oligochaetes. In Saginaw Bay, the distribution of L. hoffmeisteri correlates well with the known flow of the river out of the bay (Brinkhurst, 1967). This may demonstrate the presence of a polluting inflow, but observations on another bay with "unpolluted" inflow are required for comparison. Experts generally agree that sediment quality in Saginaw Bay may be of significant infleunce in such a distribution but the specific characteristics of the sediment (e.g., type of food materials) responsible have not yet been defined. More remote inshore areas have organisms common to smaller inland lakes, such as leeches, various midges, snails, caddisflies, mayflies and amphipods (*Gammarus* and *Hyallela*).

Quantity of these benthic forms also varies between inshore and offshore areas: studies in 1965 indicate that average density is six times greater in Saginaw Bay than in deeper water (Schuytema and Powers, 1966). In the same studies, all Lake Huron samples (Georgian Bay excluded) average 2,100 organisms per square meter, about half of the average computed from similar sampling in Lake Michigan.

A filamentous green alga, *Cladophora*, grows in the inshore areas of Lake Huron, sometimes to nuisance proportions. Its presence seems mainly dependent on suitable substrate for attachment, water movement, adequate light, and nutrients in excess of those normally available in the lake. Studies by the Ontario Water Resources Commission indicate that application of phosphorus can cause sizable growth in locations devoid of the alga before application (Neil and Owen, 1965).

Changes in Water Quality. Data for determining historic trends in water quality of Lake Huron are almost nonexistent. [1] Observations useful for detecting environmental changes are mostly limited to chemical characteristics. The best summary of such changes is given by Beeton in his paper (Beeton, 1965), "Eutrophication of the St. Lawrence Great Lakes":

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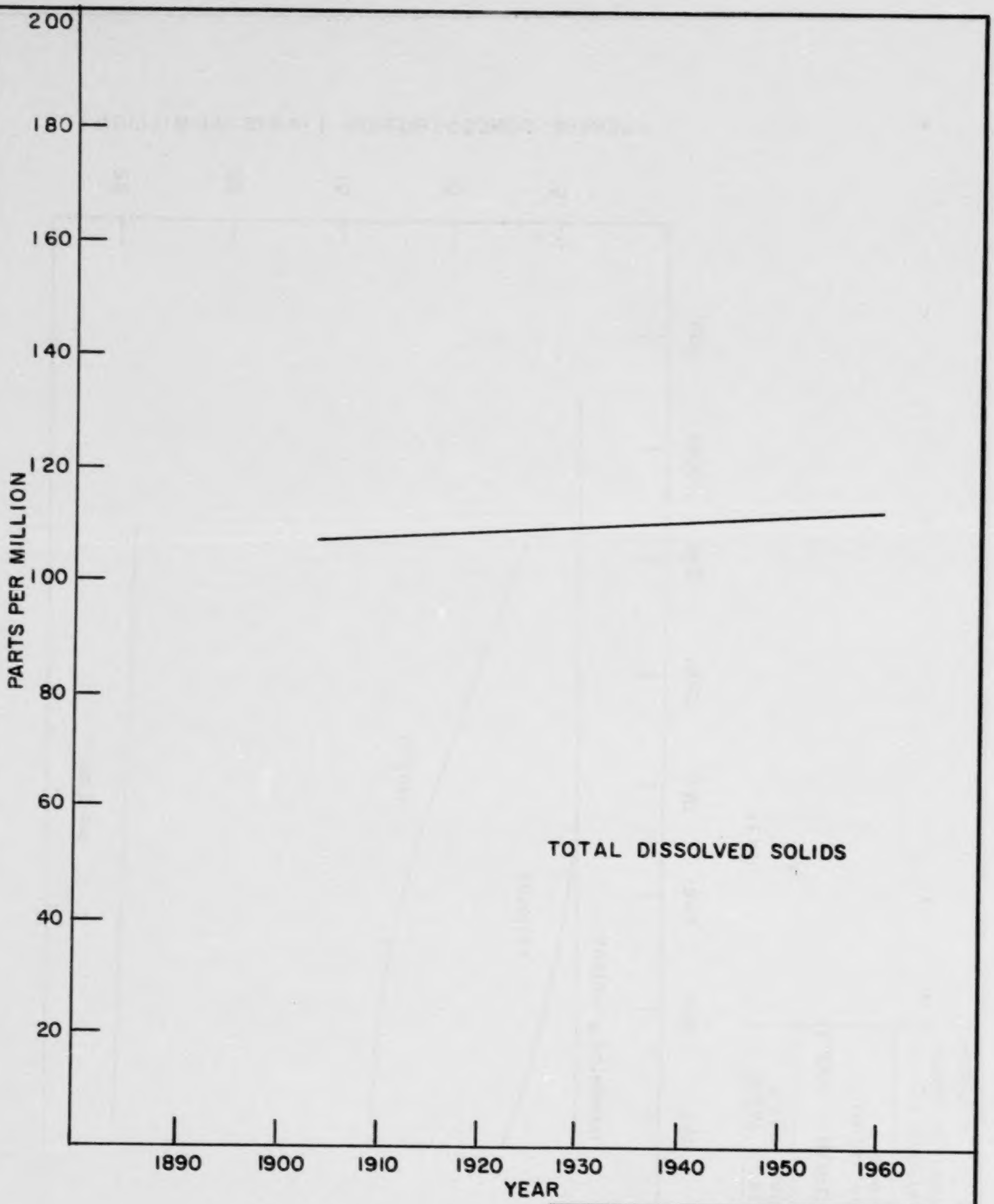
[1] Considerably more data on water quality in Lake Huron have recently been collected. In 1965 the FWPCA conducted an extensive sampling program of a number of physical, chemical, biological and microbiological parameters. A complete analysis of these data is expected soon.

> "The slight increase in total dissolved solids in this lake is probably real, since about 30 percent of the inflow to Lake Huron is from Lake Michigan, where dissolved solids have risen significantly (Figure 6). The sodium-plus-potassium content has remained about the same over the years of record. Some rather low values were reported for these ions during the 1930's, but the 1890-1910 data agree with recent determinations (Figure 7). An increase of 3 ppm in chloride appears to have occurred during the past 30 years. The major source of chlorides within the Lake Huron watershed is in the Saginaw Valley, where considerable quantities of brine are pumped to the surface in the oil fields and for use in the chemical industry. The increased influx of brine during the past 30 years may account for most of the increase in chloride in the lake. Sulfate concentrations have increased 7.5 ppm in the past 54 years."

ST. MARYS RIVER

The St. Marys River is the channel connecting Lake Superior to Lake Huron. The difference between levels of Lake Superior and Lake Huron is 20 feet, most of which is in the upper St. Marys River. The headwater of the river begins at Sault Ste. Marie where Lake Superior water passes over a rapids, through two hydroelectric power plants, and through the five shipping locks. Some water is also bypassed through Sault Ste. Marie, Michigan, via a canal which has a hydroelectric power plant at the lower end. The canal receives a few storm sewers but otherwise its waters remain unaltered. From its origin, the St. Marys courses eastward about two miles to a point where it splits into two channels past Sugar Island and Neebish Island. The channel to the west of the islands is partly man-made and is occasionally



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
CONCENTRATION CHANGES OF TOTAL
DISSOLVED SOLIDS — LAKE HURON

U.S. DEPARTMENT OF THE INTERIOR
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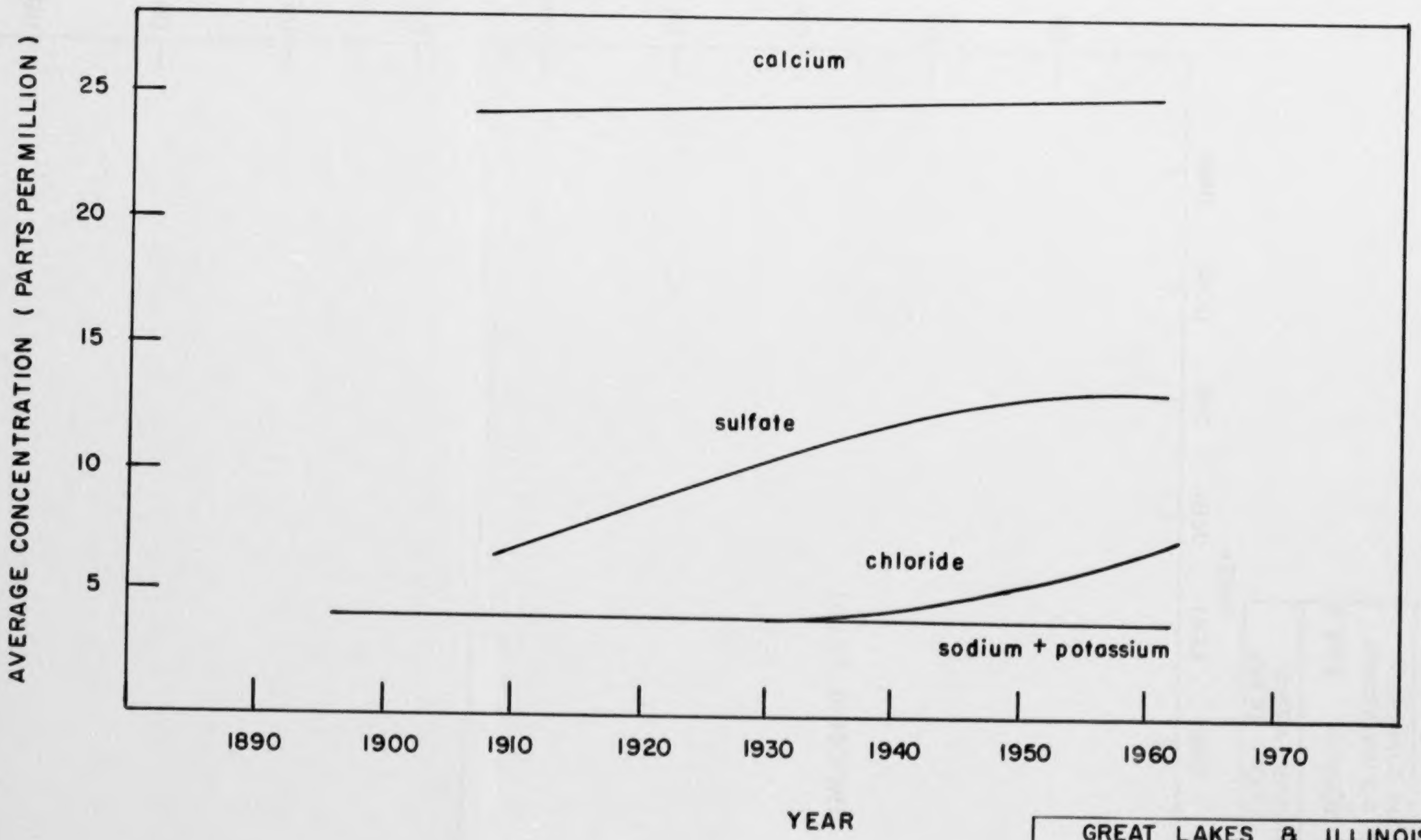
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 6



GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES

CHEMICAL CHANGES-LAKE HURON
(FROM BEETON, 1965)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 7

dredged to accommodate deep draft vessels. The outfall from the Sault Ste. Marie, Michigan, sewage treatment plant enters this channel. The channel to the north and east of the islands carries water which is primarily influenced by the industrial and urban complexes of Sault Ste. Marie, Ontario. This channel receives the outfall from the Sault Ste. Marie, Ontario, sewage treatment plant. Industrial waste is usually evident in the form of an oil slick which covers the surface for more than 20 miles from its origin. The course of the oil slick is easily altered by wind. Oil sludge also covers the bottom, especially where the sediment is primarily mud.

The north channel carries no deep draft vessels and has remained undredged for many years. At depths less than about 25 feet, thick beds of rooted vegetation cover most of the bottom, especially in summer. Species of Potamogeton compose most of the rooted plants. In places of gentle or negligible flow, species of *Myriophyllum* and *Isoetes* and *Eleocharis acicularis* cover the bottom. Beds with varying proportions of *Potamogeton richardsonii*, *P. praelongus*, and *P. zosteriformis* are common. *P. robbinsii* is frequently abundant on the bottom of bays. *P. strictifolius* and other narrow-leaved species are frequently present and in late summer and fall commonly contribute to floating mats of broken vegetation. The beds of vegetation afford shelter not only to fish but also to various zoobenthos such as snails (*Physa*), oligochaetes of the family Naiddae, and hydra. Occasionally sponges (*Spongilla*) are found attached to quillwort (*Isoetes*). Unionid and sphaeriid clams are common. Species of *Pisidium* are, by far, the most abundant. Among snails, *Amnicola*, *Campeloma*, and *Lymnaea stagnalis* are most widespread and abundant.

Commonly the shores are bordered by vegetation such as sedges (Eleocharis and Scirpus), horsetail (Equisetum fluviatile), and willows (Salix.) Beds of these emergent plants provide a habitat for many immature insects. Under stones and other objects, crayfish, sculpins, and leeches (especially (Haemopsis) are common inhabitants of shallow water.

MAJOR SUBBASINS

Of Lake Huron's 72,620 square mile basin, 49,610 square miles are land drainage, of which slightly over 15,000 square miles are within the United States. Nearly 20 percent of the U. S. drainage flows from the St. Marys River or directly into Lake Huron through numerous small tributaries. The remaining 80 percent (approximately 12,000 square miles) consists of major subbasins in the Lower Peninsula of Michigan (Figure 8) ranging in size from 135 to 2,500 square miles (Table 3).

The Saginaw River Subbasin consists of the Tittabawassee, Shiawassee, Flint, and Cass Rivers, plus several minor tributaries flowing directly into the Saginaw River. With a drainage area of nearly 6,500 square miles, the Saginaw River is the largest single basin in the State of Michigan.

The water quality of Lake Huron is determined, to a great extent, by soil types and land use in the basin. It is evident in Table 3 that soils having low water-holding capacities are located in the northern portion of the drainage. The streams draining this area are comparably stable throughout the year and generally clear.

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
MAJOR U.S. TRIBUTARIES
TO LAKE HURON

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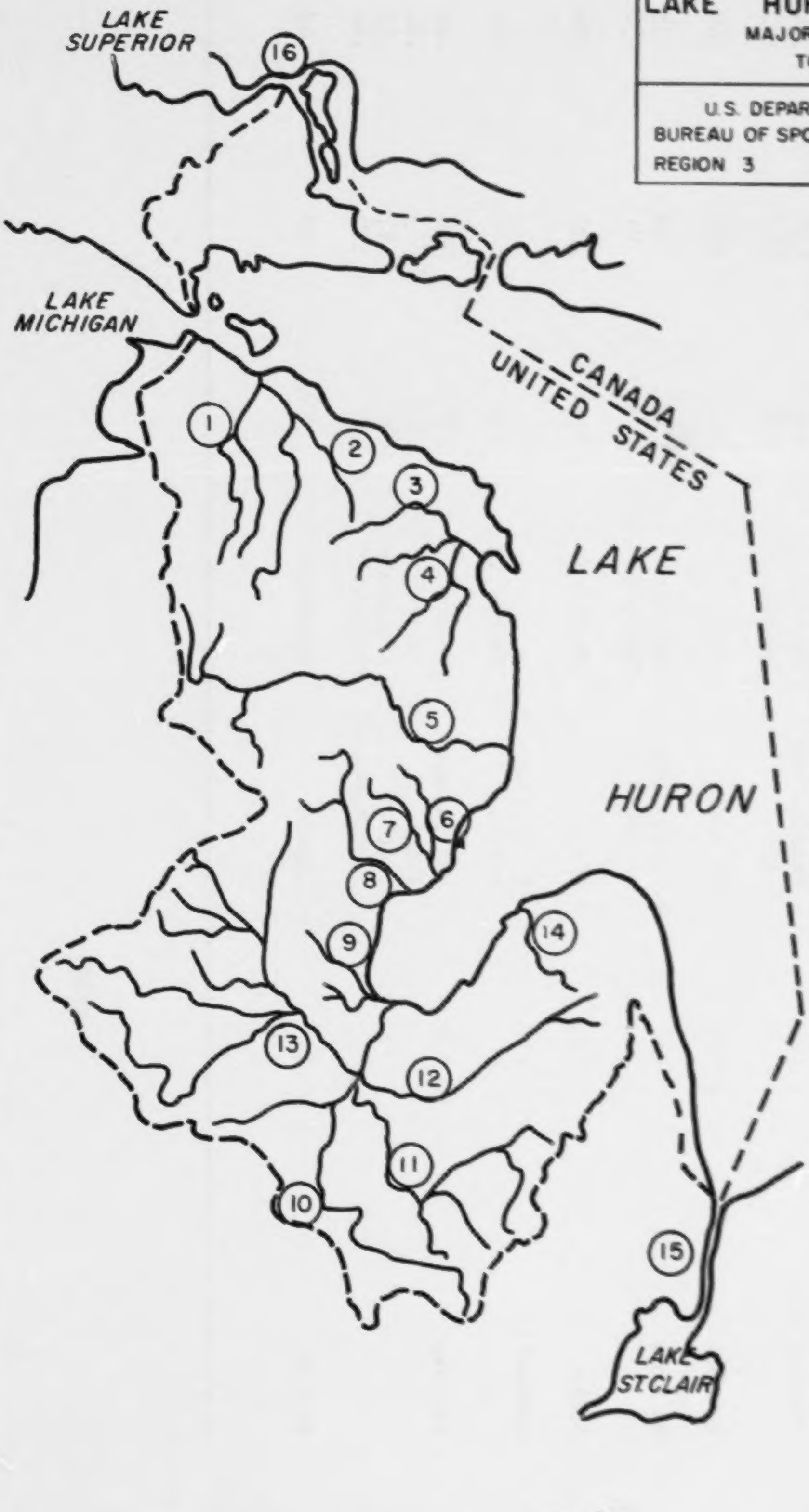
REGION 3 MINNEAPOLIS, MINNESOTA


LAKE SUPERIOR
LAKE MICHIGAN
CANADA
UNITED STATES
LAKE HURON
LAKE ST.CLAIR
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1 CHEBOYGAN RIVER
2 BLACK RIVER
3 NORTH BRANCH OF THUNDER BAY RIVER
4 THUNDER BAY RIVER
5 AU SABLE RIVER
6 EAST BRANCH OF AU GRES RIVER
7 AU GRES RIVER
8 RIFLE RIVER
9 NORTH BRANCH OF KAWKAWLIN RIVER
10 SHIAWASSEE RIVER
11 FLINT RIVER
12 CASS RIVER
13 TITTABAWASSEE RIVER
14 PIGEON RIVER
15 ST. CLAIR RIVER
16 ST. MARYS RIVER

FIGURE 8

Table 3. Total Drainage Areas of Subbasins and Partial Average Discharges of Major Rivers Tributary to Lake Huron

Subbasin	Total Drainage Area (Sq. Miles)	River	Gauging Station Location	Area Above Station	Ave. Discharge at Station	
					Cu. Ft. Per Second	cfs per Sq. Mile
Cheboygan	1,594	Cheboygan	Cheboygan	865	775	0.90
		Black	Cheboygan	597	421	.71
Thunder Bay	1,120	Thunder Bay	Bolton	588	438	.74
		N.Br. " "	Bolton	184	102	.55
AuSable	2,035	Au Sable	Mio	1,100	926	.84
Au Gres	435	E.Br.Au Gres	McIvor	84	63	.75
		Au Gres	National City	169	94	.56
Rifle	370	Rifle	Sterling	320	302	.94
Kawkawlin	150	N. Br. Kawkawlin	Kawkawlin	101	54	.53
Saginaw	6,490	Shiawassee	Fergus	637	394	.62
		Flint	Fosters	1,120	673	.60
		Cass	Frankenmuth	848	447	.53
		Tittebawassee	Midland	2,400	1,548	.64
Pigeon	135	Pigeon	Owendale	55	27	.49

The sandy texture allows water to percolate fairly rapidly, influencing the water's transparency and rivers stabilized flow characteristics. Streams in the northern drainage provide a source of high quality waters to Lake Huron.

In contrast, the heavier clay soils of the Saginaw Valley present problems in drainage, silt, high nutrients, and high organic matter. Generally, water quality of streams in this area is poorer than that of northern basin waters.

There has been little effective change in land use in the north. Lands remain forested, although nearly all are second-growth timber consisting primarily of jack pine, oak, aspen, and pin cherry. The great white and red pine stands were logged in the last four decades of the 19th Century (Michigan Water Resources Commission, 1967). Second growth timber has also replaced some ill-advised attempts at agriculture. Up to 60 percent of the land in the forested counties of the north is in public ownership. The southern drainage ranges from 0.3 to 8 percent public land. Over 80 percent of the land in some of the southern counties is in agriculture, compared to less than two percent in Crawford County in the north. Forested area ranges from 93 percent in Crawford County to 11 percent in Shiawassee County.

Because of the heavy, clay soils to the south, agriculture could not prosper without artificial drainage. In 1960 nearly 4.4 million acres of artificially drained land existed in the Michigan portion of the Lake Huron Basin. As a result, turbidity in southern streams is high.

Specific data on water quality of representative streams of Michigan draining into Lake Huron are shown in Table 4. These data were collected from 1963-1965 at water quality stations located at tributary outlets to Lake Huron and were gathered by the Michigan Department of Public Health and the Michigan Water Resources Commission.

Most streams of the upper Lower Peninsula have good water quality. Thunder Bay at Alpena, Michigan, however, has been the subject of pollution surveys since the early 1950's. Pollution problems in the Thunder River stem from pollution by municipal and industrial wastes.

With the exception of local areas near Grayling and Roscommon, Michigan, the AuSable River has excellent water quality. Sewage effluents from these two municipalities have had minor adverse effects on the river's water quality. Effluents from cottages enter the river at several points. Unless septic tank wastes are eliminated, serious pollution problems from cottages may arise in the future. Litter, a companion to pollution, is a serious problem on the AuSable and has created hazards not only to canoeists but also to wading anglers (Photo 1). Thoughtless picnickers, campers, and cottage owners reduce recreation and biological values of sections of the AuSable.

Table 4. Representative Tributaries to Lake Huron - Water Quality Data, 1963-1965

River -	Saginaw	Kawkawlin	Rifle	AuSable	Thunder Bay	Cheboygan
Temperature °C	-2	-2	-2	-2	-2	-2
	29	26	24	26	24	25
	12	11	11	9	9	10
O_2 (mg/l)	1.0	2.0	6.4	6.6	7.0	7.6
	11.8	22.8	14.0	13.0	12.5	13.2
	6.8	9.2	9.8	10.0	10.0	11.2
BOD (mg/l)	2.2	1.0	.5	.8	1.6	.8
	9.0	16.0	3.1	3.0	5.4	3.0
	4.3	4.1	1.8	1.7	2.8	2.1
Suspended solids (mg/l)	8	6	4	0	0	0
	141	92	166	38	29	41
	31	41	23	8	9	9
pH	7.6	7.4	7.6	7.5	7.5	7.9
	8.3	9.3	8.5	8.6	8.4	8.5
	8.0	8.3	8.2	8.2	8.1	8.3
Conductance	440	260	270	220	240	250
	1700	2000	530	350	500	340
	1070	650	420	290	350	300
NO_3 (mg/l)	.5	0	0	0	0	0
	12.0	18.	2.3	1.9	1.8	1.8
	3.1	1.9	.6	.2	.2	.1

(continued on next page)

Table 4. Representative Tributaries to Lake Huron - Water Quality Data, 1963-1965

River -	Saginaw	Kawkawlin	Rifle	AuSable	Thunder Bay	Cheboygan
Cl (mg/l)	50	9	3	0	0	0
	402	400	32	5	8	2
	216	81	17	1	3	0
BO_4 (mg/l)	0	0	0	0	0	0
	1.4	1.1	.3	.4	.4	.3
	.5	.2	0	0	.1	0
Detergents AD (mg/l)	0	0	0	0	0	0
	.6	.6	.2	.2	.2	.2
	.2	.1	0	0	.1	0
Ammonia (mg/l)	.2	0	0	0	0	0
	2.5	2.0	.5	.4	.6	.2
	.8	.2	.1	0	.1	0

The first row opposite each water quality item represents the maximum, the second the minimum, and the third row is the median.

Photo 1. Litter has become a problem near the mouth of the AuSable River.

The AuGres River generally has good water quality. Some stretches of the river are adversely affected by turbidity associated with runoff from agricultural lands. This situation also exists in the Pine River (Alcona and Iosco Counties); in addition, several impoundments have been deleterious to the Pine's trout fishery by raising water temperatures and impeding fish movement. Erosion of stream banks and extensive trampling of the shoreline by grazing cattle have also reduced the value of the aquatic habitat.

The Chippewa River receives pollution from refinery effluents and wastes from food processing plants. Municipal wastes have also degraded this river.

Four major tributaries to the Saginaw River--the Tittabawassee, Shiawassee, Flint, and Cass Rivers--have pollution problems stemming from municipal and industrial wastes. A 1965 biological survey of the Saginaw River from the City of Saginaw to Saginaw Bay, conducted by FWPCA, revealed gross pollution throughout the river. Few aquatic organisms were found except for pollution-tolerant forms, such as sludgeworms. At every sampling point there were distinct odors of grease, oil, and sewage (Photo 2).

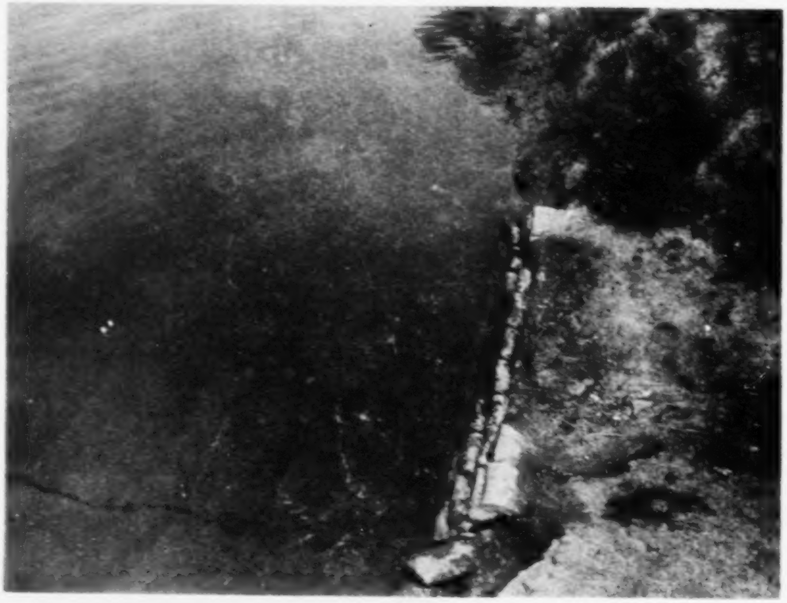

Photo 2. An oil slick near the mouth of the Tittabawassee River is one source of pollution which contributes to fish kills in this sector of the river.

Water quality of Saginaw Bay is largely determined by the inflow from the Saginaw River. The river discharges large quantities of wastes into the bay from industrial, municipal, and agricultural sources. Extensive algae blooms in the river and the bay have resulted. Some dilution of these polluting materials occurs before bay currents reach Lake Huron proper. Bay waters are high in concentrations of calcium, sodium, potassium, chloride, and sulfate. The temperature of bay waters is somewhat higher than that of Lake Huron waters, partly due to high mineral concentrations and to the shallow water of the bay.

Following several biological studies of the bay by State and Federal biologists, the Michigan Water Resource Commission (1967) reached two conclusions regarding water quality of Saginaw Bay. In part, these conclusions were:

1. Water zones of the bay which were closest to the mouth of the Saginaw River harbored the greatest number of pollution-tolerant organisms. Conversely, zones farthest from the mouth of the river had the greatest number of sensitive animals. This fact suggested that water quality of the Saginaw River affected distribution of bottom animals in the bay.
2. The distribution of tolerant, burrowing type species was closely correlated with sediment quality as well as water quality.

Generally, Lake Huron waters are of excellent quality. Water is low in turbidity and hardness. A major pollution problem in lower Lake Huron is located on the "Thumb" at Harbor Beach. Grain processing wastes are discharged directly into Lake Huron and have had serious effects on its waters. Most serious damage has been done to aquatic habitats in the enclosed area behind the breakwall at Harbor Beach. The high organic content of the water has reduced the dissolved oxygen content to critical levels. Soluble phosphates in the grain wastes have also stimulated the rapid growth of undesirable aquatic plants. The heavy weed growth in the harbor area interferes with fish and small boat navigation.

FISH AND WILDLIFE RESOURCES

In this section of the report, fishery resources of Lake Huron will be discussed largely in the Commercial Fisheries sub-section. Inland stream and lake discussions are located in the Sport Fishery sub-section.

COMMERCIAL FISHERIES

Historical Background. Commercial fishing on Lake Huron became an established industry in the mid-1800's as the expanding population of the region, which followed construction of the Erie Canal, created demands for fishery products.

Prior to the coming of the Europeans, various Indian tribes had established fishing grounds on the lake in the Straits of Mackinac and Saginaw Bay. Spears, dip nets, hook and line, and elm bark gill nets were used to harvest lake trout, whitefish and sturgeon. In 1835 conventional gill nets appeared in use around Alpena and became widespread in the deeper open waters of the lake within the next 15 years. Lake trout and whitefish were the main species harvested with gill nets although perch and suckers were also taken off Harbor Beach in the southern portion of the lake. Seines were introduced in Lake Huron around 1841 and used primarily for taking suckers and walleye in the Pine and AuSable Rivers. This gear did not come into intensive use until the early 1900's when carp production began in Saginaw Bay. Most of the fyke net fishing was carried on in the Saginaw River through the ice and the principal species taken were yellow perch, suckers and catfish (Michigan Water Resources Commission, 1967).

By far the most important gear fished at the turn of the century were pound nets and trap nets which together accounted for over 75 percent of total landings in 1899. The pound net was introduced around 1860 and used in all areas of the lake; trap nets appeared in the 1890's. The largest concentration of pound nets was found in the shallow waters of Saginaw Bay where bottom conditions were suitable for driving and holding the net stakes. Almost the entire catch of herring, yellow perch and walleye was taken with this gear.

Commercial production rose steadily between the mid-1800's and the turn of the century, reaching a peak in 1902 when over 20 million pounds were landed. Annual harvests remained relatively stable through the 1920's with a slight downward trend toward the end of the period. Lake Huron ranked third in commercial fishery landings during these years, behind Lake Erie and Lake Michigan. Following introduction of the deep trap net from Lake Ontario in 1929, landings rose from 8.8 million pounds in 1929 to over 16 million pounds in 1931, largely due to the efficiency of this gear for taking whitefish. Use of the deep trap nets was severely limited by regulation in 1935. In the late 1930's sea lamprey predation was evidenced in the drop of whitefish, lake trout and sucker landings and an almost steady decline in total production has continued through 1966. Accompanying decreased production has been an increase in the proportion of lower valued species in the commercial catch. In 1966 only yellow perch and chubs of the major species landed had ex-vessel prices over 10 cents per pound. The average value of the catch in 1966 was 15 cents while, in contrast, the average value of the catch in the period 1930-34 at 1966 prices was 31 cents per pound. Table 5 summarizes total Great Lakes commercial fishery landings and values by decade from 1920-1959, and annually thereafter.

Table 6 shows the production of the Lake Huron commercial fishery since 1879 by species. Statistics are complete from 1911 through 1966. The average harvests for decades or other groupings prior to that time are based on data for the years 1879, 1885, 1889-90, 1892-97, 1899, 1903, and 1908. Tables 7 and 8 indicate species composition of the commercial catch for the period 1930-1966 in the open lake and Saginaw Bay.

The decline of the traditional high valued species has been responsible to a large degree for the production in active U. S. commercial fishermen operating on the lake (Table 9). The total number employed dropped from slightly more than 1,000 in the early 1920's to 346 in 1957. With the revival of the chub fishery in the open lake, the number employed temporarily increased and average gross earnings per fisherman rose over 50 percent between 1956 and 1960. As chub landings declined after 1961, the number of employed fishermen was reduced to 303 in 1966, the lowest on record. The recent upturn in yellow perch production in Saginaw Bay brought average earnings up to $2,223 per fisherman, an historic high for Lake Huron but still some $500-700 below the average for Lake Erie and Lake Michigan.

Table 5. Average Commercial Landings and Value of Fish from the Great Lakes, United States and Canada Combined

Years	Landings (Millions of Pounds)	Value (Millions of Dollars)*
1920-1929	106.2	8.8
1930-1939	111.7	7.6
1940-1949	101.1	14.9
1950-1959	111.3	15.6
1960	104.5	10.8
1961	113.4	11.4
1962	116.4	9.5
1963	99.6	9.3
1964	88.6	9.5
1965	96.8	10.8
1966	115.6	10.3

*Dollar values uncorrected for general price level increases caused by inflation.

Table 6. Average Combined Production of Certain Species [1] for Specified Periods in the Commercial Fisheries of the United States and Canadian Waters of Lake Huron, 1879-1965, in thousands of pounds

Period	Sturgeon [3]	Lake Herring [4]	Chubs [4]	Whitefish	Lake Trout	Carp [5]	Sucker [6]	Yellow Perch	Walleye	Other	Total
1879-1909 [2]	411	[5]	[5]	3,585	6,143	-	2,250 [7]	2,293	2,397	6,692 [8]	23,771
1910-1919	52	4,583	862	2,369	5,823	589	1,866 [7]	1,888	1,502	964	20,498
1920-1929	28	3,890	1,133	2,852	5,169	866	1,732 [7]	708	1,218	1,124	18,720
1930-1934	20	4,249	1,418	5,087	4,984	1,015	2,157 [7]	700	1,747	1,033	22,410
1935-1939	14	5,135	786	2,649	5,320	886	1,695 [7]	940	2,439	364	20,228
1940-1944	9	2,711	513	936	2,776	941	1,300 [7]	936	1,881	1,001	13,004
1945-1949	13	1,673	361	2,151	589	1,615	1,362	691	830	885	10,170
1950-1954	21	1,640	423	4,612	414	1,530	1,274	852	568	775	12,109
1955-1959	33	167	1,582	889	31	1,594	786	721	510	761	7,074
1960-1964	17	58	4,233	1,011	1	1,470	709	1,337	455	608	9,899
1965	17	59	2,840	790	1	1,460	539	1,322	432	780	8,240
Largest Catch	1,041	8,086	5,570	7,694	7,484	2,431	4,020	4,588	3,580	-	28,050
Year of Largest Catch	1885	1916	1961	1892	1893	1945	1906	1912	1899	-	1902

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[1] Species whose annual production has exceeded one million pounds.
[2] Average for years of record.
[3] Fishing prohibited in Michigan 1928-1950
[4] Catches of Lake Herring and Chubs combined through 1908.
[5] Canadian data not available until 1902.
[6] Canadian data not available until 1952.
[7] United States production only
[8] Comprised mainly of Herring and Chubs.

Table 7. Average U. S. Commercial Fishery Production for Specified Periods of Nine Major Commercial Species in Saginaw Bay and Lake Huron Excluding Saginaw Bay.

Species	(Thousands of Pounds) 1930-34	1935-39	1940-44	1945-49	1950-54	1955-59	1960-64	1965	1966
Carp									
Open Lake	25	45	163	146	211	63	68	40	62
Saginaw Bay	925	794	729	1409	1247	1420	1343	1384	769
Catfish									
Open Lake	-	2	10	6	8	5	3	1	2
Saginaw Bay	45	102	340	249	248	311	201	145	164
Chubs									
Open Lake	517	256	141	133	120	850	2086	1326	802
Saginaw Bay	tr	tr	tr	tr	3	74	247	21	5
Herring									
Open Lake	927	1056	563	496	417	41	17	42	16
Saginaw Bay	2901	3823	1827	1003	1098	87	23	tr	tr
Lake Trout									
Open Lake	1639	1350	602	42	tr	tr	tr	-	-
Saginaw Bay	260	75	74	4	tr	-	-	-	-
Suckers									
Open Lake	852	846	491	473	236	66	48	36	14
Saginaw Bay	1305	849	809	889	904	540	484	353	299
Walleye									
Open Lake	169	174	100	101	108	74	63	76	34
Saginaw Bay	1173	1379	1501	411	64	62	59	25	17
Whitefish									
Open Lake	2112	918	127	943	123	59	225	172	171
Saginaw Bay	1282	116	19	507	11	3	47	3	1
Yellow Perch									
Open Lake	101	148	90	56	69	98	189	71	97
Saginaw Bay	517	606	530	394	376	319	375	895	1221
TOTAL (All Species)									
Open Lake	6410	4880	2359	2450	1348	1311	2743	1788	1212
Saginaw Bay	8602	7837	5891	4964	4178	3023	2944	2885	2557

Table 8. Percentage Composition by Major Species of U. S. Commercial Fishery Production for Specified Periods in Saginaw Bay and Lake Huron Excluding Saginaw Bay*

Species	1930-34	1935-39	1940-44	1945-49	1950-54	1955-59	1960-64	1965	1966
Carp									
Open Lake	tr	1	7	6	16	5	2	2	5
Saginaw Bay	11	10	12	28	30	47	46	48	30
Catfish									
Open Lake	tr	1	6	5	6	10	7	5	6
Saginaw Bay	tr	1	6	5	6	10	7	5	6
Chubs									
Open Lake	8	5	6	5	9	65	76	74	66
Saginaw Bay	tr	tr	tr	tr	tr	2	1	1	tr
Herring									
Open Lake	14	22	24	20	31	3	1	2	1
Saginaw Bay	34	49	31	20	26	3	1	tr	tr
Lake Trout									
Open Lake	26	28	25	2	tr	tr	--	--	--
Saginaw Bay	3	1	1	tr	tr	--	--	--	--
Suckers									
Open Lake	13	17	21	19	17	5	2	2	1
Saginaw Bay	15	11	14	18	22	18	16	12	12
Walleye									
Open Lake	3	4	4	4	8	6	2	4	3
Saginaw Bay	14	18	25	8	2	2	2	1	1
Whitefish									
Open Lake	33	19	5	38	9	tr	8	10	14
Saginaw Bay	15	1	tr	10	tr	tr	--	tr	tr
Yellow Perch									
Open Lake	2	3	4	2	5	7	7	4	8
Saginaw	6	8	9	8	9	10	13	31	48

*Percentages do not sum to 100 due to rounding.

Table 9. Commercial Operating Units and Productivity in the United States Waters of Lake Huron, 1922-1966

Year	Number of Fishermen	Pounds Landed per Fisherman	Value of Catch per Fisherman	Number of Vessels	Number of Boats
1922	1,001	13,928	944	29	248
1930	1,118	13,700	1,181	60	363
1931	1,182	13,931	1,278	65	337
1932	1,228	12,552	931	66	341
1934	1,293	11,129	738	61	299
1936	836	15,232	1,196	43	232
1937	931	12,722	1,023	36	246
1938	954	12,613	796	33	260
1939	1,039	12,852	833	35	296
1940	667	13,641	1,019	44	175
1950	513	9,889	802	48	184
1954	491	11,041	1,154	35	186
1955	373	12,228	1,299	30	137
1956	376	9,667	1,022	35	157
1957	346	9,656	1,250	29	152
1958	446	11,421	1,516	44	172
1959	499	10,102	1,635	65	161
1960	566	11,199	2,206	81	172
1961	569	12,158	2,096	82	172
1962	485	12,124	1,849	70	208
1963	426	12,220	1,842	71	182
1964	404	10,134	1,679	62	163
1965	353	13,238	2,223	59	149
1966	303	12,439	1,813	45	49

In 1966, Saginaw Bay accounted for 68 percent of total Lake Huron landings, a slightly higher proportion than prevailed in the 1930's. Major commercial fishing ports include Bayport, Tawas City, Sebewaing, and the Standish area on Saginaw Bay; Alpena, Cheboygan, Oscoda, and Rogers City on the central and northern portions of the lake and Harbor Beach in the south. In 1966 fishermen in the Bayport area accounted for 33 percent of total lake landings and almost 50 percent of the Saginaw Bay catch, while 75 percent of the open lake landings were attributed to Alpena, Harbor Beach, Oscoda, and Rogers City. Some 30 towns on Lake Huron recorded commercial fish landings in 1966.

Fishery Base. The commercial fishery in Lake Huron during the *early period* (1879-1930) paralleled development of the fishery in the other upper Great Lakes. In comparison with recent years, the catch included a relatively large number of species which contributed significantly to total landings. During the period 1879-1909, six species accounted for over one million pounds average annual landings including herring, whitefish, lake trout, suckers, yellow perch, and walleye. Landings of each of these species fluctuated somewhat throughout the period but no overall pattern is available that would indicate long run increases or declines in abundance.

Two significant changes were recorded in the commercial landings. One was the appearance of carp in the catch following its introduction into the United States in 1874. Production rose from zero in 1898 to over one million pounds by 1917. The lake sturgeon catch which accounted for over 500,000 pounds in 1889 was insignificant by 1909. This decline is attributed to the intensive effort to remove sturgeon from areas where they damaged gear fished for other species. Since sturgeon was of little commercial significance at the time, the catch was often discarded or left on the bank. Because of their slow growth and late maturity, the species was soon reduced to insignificance for commercial production.

Prior to 1929, statistical discrepancies in the geographical area covered by Saginaw Bay prevented an accurate allocation of landings between the bay and the open lake. It appears, however, that whitefish, lake trout, and chub dominated the open lake catch while Saginaw Bay accounted for the major portion of lake herring, walleye, carp, yellow perch, and sucker production. Tributary streams did not contribute directly to the commercial catch.

Major changes in the fishery base of Lake Huron occurred during the middle period (1930-1959) resulting from a number of possible factors including sea lamprey predation, instances of overfishing, and the spectacular increase in abundance of alewives.

Relatively few changes were recorded in species composition and total landings of the commercial fishery until the late 1930's. At that time predation by the sea lamprey, first recorded in Lake Huron in the 1930's, began to be reflected in landings of lake trout and whitefish. The United States lake trout catch dropped from almost 2.2 million pounds in 1932 to less than 500 pounds in 1949. Whitefish landings, although typically more erratic than lake trout, appeared to have declined at about the same time, dropping from 4.1 million pounds in 1932 to 0.09 million pounds in 1942.

The collapse of the whitefish fishery may have been hastened by use of the deep trap net in Lake Huron starting in 1929. This gear, first developed on Lake Ontario, was particularly efficient for capturing whitefish, and its use became wisespread on Lake Huron during the early 1930's (Van Oosten, et al., 1946). In 1935, restrictions were imposed that prohibited setting traps in water deeper than 80 feet, thereby effectively eliminating the use of this gear for whitefish. However, whitefish landings continued to decline after 1935 as lamprey predation further depleted stocks. A brief upturn in landings was recorded from 1946 to 1949 based on the very successful 1943 year class, but since then the catch has not exceeded 0.4 million pounds.

Walleye production in Saginaw Bay fluctuated, but without a long term trend until the early 1940's. Prior to 1930, landings ranged between a low of 314,000 pounds (1924) and a high of 1,803,000 pounds in 1918. Between 1930 and 1943, landings rose to over 1,000,000 pounds in all years but 1931. After 1943, production began a steady decline reaching a low five-year average in 1955-59 of only 62,000 pounds in Saginaw Bay. The only variation from this progressive decline occurred in 1946 when landings rose slightly as a result of the very strong 1943 year class becoming available to the fishery.

Several factors have been associated with the low level of walleye abundance reached by the end of the period. Industrial pollution in

Saginaw Bay has been suggested by fishermen operating in the area. It has also been noted that the timing of the walleye decline is quite similar to that of the lake trout and whitefish indicating that the sea lamprey may have contributed to the collapse of the walleye fishery. Although observations are not available on the incidence of scarring, the seasonal movements of walleye into deeper water in the late summer when parasitic-phase lampreys are moving toward shore provides additional evidence that lamprey predation may have been a significant causal factor (Hile and Buettner, 1959).

Commercial production of other species not subject to lamprey predation also declined during these years. The drop in production of lake herring, yellow perch, and suckers in Saginaw Bay was attributed to decreased fishing effort rather than a lesser abundance (Hile and Buettner, 1959). Yellow perch in Saginaw Bay were especially underexploited, resulting in slower growth rates relative to perch stocks of the other Great Lakes. It is believed that as a result few fish of legal size ($8\frac{1}{2}$ inches) were available to the fishery by the mid-1950's. Increases in abundance and lower production of suckers and lake herring were also indicated at least through 1950.

Only three major species, carp, catfish, and chubs, exhibited above average production and abundance after 1940. Average carp landings in Saginaw Bay rose from 950,000 pounds during the period 1930-34 to almost 1.5 million pounds in 1955-59. A similar increase was noted for catfish. In the open lake, chub catches for 1955-59 exceed any similar period over the years of record.

The first alewife specimen was recorded from Lake Huron in 1933 although they were undoubtedly present earlier (Miller, 1956). It is believed that the alewife gained access to Lake Huron from Lake Ontario through the Welland Canal and Lake Erie although there has been speculation that the Trent River system provided direct access from Ontario. A build-up in alewife abundance was not noted until the early 1950's when alewife catches increased markedly in experimental pound nets around 1953 and 1954 (Table 10). The rapid build-up of alewives appears to be responsible for the decline in abundance and production of the lake herring in Saginaw after 1952, although the causal relationship is not clear (Miller, 1956).

Table 10. Catch of Alewife and Lake Herring in South Bay, Lake Huron, Ontario* (All fish taken in 1½ inch mesh five-pound nets fished in same location).

Year	Pounds Alewife	Pounds of Herring	Number of Lifts
1951	0.2 (1 fish)	36,018	175
1952	1.0 (5 fish)	14,119	163
1953	6.0 (51 fish)	12,625	65
1954	2,316	8,731	97
1955	16,302	4,841	86
1956	22,428	3,476	93

*From Miller, 1956, p. 103.

Trends in abundance and production of the previous period have continued to the present recent period (1960-present). The most recent five-year production average for Saginaw Bay was the lowest on record.

A similar situation would have prevailed in the open lake had not the chub catch increased markedly in recent years.

The two most significant departures from previous production trends were the increased yellow perch landings in Saginaw Bay in 1965 and 1966 and the gradual upsurge in chub production reaching a peak of 3.2 million pounds in 1961. After many years of relatively stable harvests, the yellow perch catch increased from 278,000 pounds in 1963 to 1,318,000 pounds in 1966 reflecting previous indices of abundance in Saginaw Bay. Two factors appear to be responsible including the elimination of certain closed seasons on perch in Saginaw Bay and, probably more important, the decline in yellow perch production on Lake Erie in 1964 and 1965. Generally in recent years Lake Erie perch have been preferred to those from Saginaw Bay and good production years on the former have resulted in lower catches in Saginaw Bay.

Chub landings in Lake Huron did not follow the pattern of Lakes Michigan and Superior. In the latter lakes, the deep water fishery concentrated on chubs following depletion of lake trout stocks by the lamprey. No such transfer of effort was apparent on Lake Huron during the period of lake trout decline from 1935 to 1940, and chub landings remained at a relatively low level (below 0.5 million pounds) between 1930 and 1956. It is known that many gill net fishermen on Lake Huron shifted their effort to Lake Michigan, following the lake trout decline in Huron in the late 1930's, because the full effects of lamprey predation were not felt on Lake Michigan until the mid-1940's. These fishermen apparently continued operating in Lake Michigan after collapse of the lake trout fishery, concentrating their effort on chubs.

The six-fold increase in chub landings on Lake Huron between 1957 and 1961 was associated with greater effort rather than a major change in abundance. Biological sampling cruises by the Bureau of Commercial Fisheries in 1956 had indicated that relatively large numbers of chubs were available to the fishery (Bureau of Commercial Fisheries, 1958a) and the dissemination of this information accounted in part for renewed effort for this species. During this period (1957-61 the square yards of gill net fished rose from 288,600 to 1,048,100 while the number of vessels operating increased from 29 to 82. This increased effort was almost entirely directed to chubs.

The present fishery base in Lake Huron appears to be dominated by the alewife. Exploratory trawl fishing by the Bureau of Commercial Fisheries in 1965 indicated that alewife was by far the most abundant species in both Saginaw Bay and the open lake (Bureau of Commercial Fisheries, 1965). Carp, smelt, and chubs were the only other species taken in significant numbers. The same species predominated catches of a similar cruise in 1966 although suckers and yellow perch were also significant. Carp accounted for over 50 percent of the lower bay catches (Bureau of Commercial Fisheries, 1966).

The build-up of alewife since 1953 probably reached a peak in 1964. The future status of the alewife in Lake Huron is uncertain, but a decline in abundance from 1964 levels is expected. The rate of decrease is likely to be considerably less than Lake Michigan because lamprey control activities on Lake Huron have not proceeded to a stage where predator species such as lake trout can be re-established to utilize a portion of the alewife population. In addition, the trawl and pound net fisheries of Lake Michigan have taken large quantities of alewife for commercial uses and such fisheries do not exist on Lake Huron.

Relatively little data is available from which to indicate future trends in the chub population. There are indications that the species has undergone changes similar to those which occurred in Lake Michigan where the bloater chub (Coregonus hoyi) now makes up the major portion of the population. It has been suggested that as a result of lamprey predation, fishing pressure, and competition from the alewife, the Lake Michigan chub fishery may collapse in the near future.

It appears likely that fish populations in Lake Huron, particularly chubs and alewives, will continue to undergo sizeable fluctuations in abundance in the near future. The recent introductions of coho salmon by the Michigan Department of Natural Resources and splake by the Ontario Department of Lands and Forests will add further to the uncertainty of predicting changes in the fishery base of the lake. It is doubtful that coho will contribute directly, in significant numbers, to the commercial catch, although they may affect the abundance of some forage species, particularly alewife and chubs, thereby influencing such predator species as splake.

A return to former levels of abundance of the highly valued lake trout, whitefish, and possibly walleye is not expected to occur until sea lamprey control is effected in the lake.

The total landings in the Canadian Lake Huron fishery have generally followed the pattern on the U. S. side. Peak harvests occurred in the late 1800's, dropping off to a relatively constant level of production between 1900 and the mid-1930's, when the effects of sea lamprey predation became apparent in the declining lake trout catch. As stocks of lake trout and whitefish dwindled, the fishery turned to other species especially chubs and yellow perch which have accounted for a large share of the catch in recent years.

The Canadian fishery is divided into three principal areas including Georgian Bay, the North Channel, and the open lake. Historically, the Georgian Bay and the North Channel fisheries were based almost entirely on lake trout and whitefish, the two species consistently accounting for over 80 percent of landings in these areas. From at least the early 1920's until 1956 the Georgian Bay and open lake catch were approximately equal, but since 1957 the open lake fishery has predominated.

There have been several historical differences between the Canadian and U. S. fisheries in regard to species composition of the catch. In general, lake trout and whitefish together represented a higher proportion of Canadian landings relative to the more diversified U. S. catch where Saginaw Bay provided a suitable habitat for such species as lake herring, carp, walleye, and yellow perch. Also, the different ecological conditions in Georgian Bay compared with the open lake have tended to favor the lake trout and whitefish. Thus, while the Canadian lake trout catch in the open lake declined over the same period of time as the U. S. catch, Georgian Bay continued to supply significant catches (over 100,000 pounds) for almost 10 years after open lake landings dropped below 100,000 pounds. This apparently was due to the survival of a trout population in the southwestern Bay where there was a delay in the establishment of a sea lamprey population.

These conditions have also contributed to maintaining a moderately strong whitefish population in the southern Bay. In addition, relatively large portions of whitefish habitat in the area are either closed to commercial fishing or unsuitable for fishing because of physical characteristics, thus placing an upper limit on rates of exploitation possible. The extremely large Canadian whitefish catch during the early 1950's was almost entirely from Georgian Bay. Landings in the Bay rose from 87,000 pounds in 1947 to 6.2 million pounds in 1953. It has been established that this increase resulted from the unusually successful 1943 year class previously referred to, but because peak landings occurred four to five years after the open lake, it appears that the growth rate of whitefish in the Bay is somewhat less than stocks of Lake Huron and other lakes (Cucin and Regier, 1965).

Any future biological program for Lake Huron must involve research and management of both the fish stocks and the habitat that supports them. Due to the close relationship of habitat to water quality considerations, it will be covered in the report section dealing with water quality.

This discussion will concern itself primarily with research program requirements of the fish stocks. It should be constantly remembered, however, that this is essentially an artificial division. The fisheries of Lake Huron and their environment are both parts of an inter-acting whole with frequent population shifts and water level and water quality changes occurring simultaneously.

Future advances in biological knowledge and management techniques may permit direct manipulation of fish stocks. Indeed, some direct management tools such as introduction of new species and sea lamprey control are currently available. Past experience in introduction of exotics into the Great Lakes has generally been unfortunate, however, and indicates the need for great caution in future experimentation. The planting of coho salmon and other anadromous species in Lake Michigan is a recent exception that has apparently proven successful.

The extent to which stocking of anadromous species will affect Lake Huron's commercial fishery is not clear. For the immediate future, the requirements of a biological program will probably be geared to providing the necessary data for indirect management; that is, prediction of abundance and distribution of various species to permit advanced adjustment by the fishery management agencies. This need is of utmost importance under conditions of limited entry management.

Against these overall management considerations a biological program oriented specifically to the conditions of Lake Huron should give priority to the monitoring of fish stocks and to species investigation.

The systematic collection and analysis of information on the abundance and biological characteristics of fish stocks is vital to the indirect management approach outlined above. Continuous sampling is necessary to keep abreast of the constantly changing structure of fish stocks, particularly the lightly-fished species. Representative samples and accompanying relevant information should be collected with due regard to the adequacy of information provided by the commercial and sport fisheries.

Information on the relative abundance, growth, and survival of the young of principal species, obtained by systematic sampling, will make it possible to forecast their abundance when they eventually enter the fishery. This knowledge would be of practical value to the industry in preparing markets and readying appropriate fishing gear and to agencies responsible for managing or carrying out investigations of the fishery.

When compared with most of the other Great Lakes, relatively little research of this nature has been carried out on Lake Huron in the past 25 years by U. S. researchers, although Ontario fishery investigators have conducted relatively extensive monitoring operations in the lake. For example, much of the data on the status of fish stocks during recent years was developed from sampling in 1955, 1959, and two exploratory fishing cruises in 1965 and 1966. It is recommended that considerably more emphasis be expended on obtaining adequate data on a continuing basis for forecasting and basic research purposes on Lake Huron.

For the long-term evaluation of the Lake Huron commercial fishery, additional data should be gathered for the following species investigations:

1. Future populations of lake trout and whitefish with sea lamprey control.
2. The extent to which abundance of the walleye has been affected by the sea lamprey and possibly by environmental factors, especially in Saginaw Bay.
3. Interaction between the alewife and lake herring and the possibility for return of the herring should alewife populations be severely reduced.
4. Present status of the chub stocks in the open lake.
5. Interaction between introduced species, particularly the salmonids (including splake) and traditional species of the commercial fishery.

Fishery Management Base. In order to obtain maximum benefits from management of fishery resources of Lake Huron, an integration of biological and economic objectives will be required. In the management of a fishery, the role of the biologist is to provide information on biological potential, while the task of the economist is to indicate the level of fishing effort within the biological potential that will produce the maximum economic return. Efficient management necessitates a joint effort. While this future management must be considered within the context of the overall Great Lakes fishery, the particular characteristics of the Lake Huron situation require special adaptations of overall Great Lakes management policies and objectives.

The presence of productive habitat and bountiful fish stocks in themselves is not a guarantee of efficient sustained fishery yield. To attain this objective, sound management of the resource is required. In analyzing the requirements for a sound management base, the following points should be kept in mind as a framework guide:

1. Overall, the Great Lakes cannot be classified as productive waters in terms of historical per acre production. Lake Erie, the most productive of the Great Lakes, has averaged only eight pounds per acre commercial production. The Saginaw Bay area has been near this figure with a seven pound per acre average since 1930, while Lake Huron (including Saginaw Bay) has averaged between 0.8 and 0.9 pounds per acre during the same period.

2. In dealing with a resource as large and diverse as the Great Lakes fishery, indirect methods of management have been employed in the past. In recent years, however, more direct methods have proven feasible, notably control of the sea lamprey in Lakes Michigan and Superior and successful introduction of such exotic species of fish as salmon and probably splake. While the long term results of these measures are not yet apparent, it appears likely that their use will increase in the future.

3. Historically, management of the U. S. Great Lakes commercial fisheries has been limited to adjusting regulations on closed seasons, fish size, and gear rather than controlling fishing effort. However, in conjunction with the program of evaluating the status of lake trout stocks, permit fishing for quotas was initiated in Lake Superior during the early 1960's. Ontario, has for a number of years, allowed entry into the Great Lakes fishery only through transfer of existing licenses.

The total number of commercial licenses is currently being reduced by the process of not renewing the license of inactive fisheries. In 1967, legislation was passed providing the Michigan Conservation Department with authority to limit the number of commercial fishermen operating, to control fishing effort, and to establish quotas for harvest of various species. By 1970 a system of commercial fishing regulations incorporating these controls will be operative. It is expected that this trend in managing the Great Lakes commercial fisheries will continue and the states will come to closely control the number of participants and fishing effort.

4. Notwithstanding the development of more direct management measures, there remains a need for continual monitoring of biological and environmental parameters. Both fish stocks and environmental conditions in most of the Great Lakes waters have undergone extremely rapid changes within the past several decades, and the construction of appropriate fisheries management programs must be based on an awareness of these changes and the timely recognition of significant trends.

Provision for the future growth and development of the commercial fishery requires a management perspective based on the entire lake, complemented by a system of flexible regulations that can adapt to fluctuating fish populations, changing economic conditions, and new technological developments. Fortunately, the Lake Huron commercial fishery has operated under only two regulatory codes, that of Michigan and the Province of Ontario. However, research has been fragmented among many agencies including state and provincial groups, the U. S.

Fish and Wildlife Service, and individual university research staffs. This has often tended towards piecemeal approaches. Recently a trend towards greater coordination and integration of management and research programs has been gradually developing. In 1955, the Great Lakes Fishery Commission was established by treaty between the United States and Canada. The Commission is charged with the implementation of a program for control of the sea lamprey and coordination of fishery research by various agencies. Establishment of a Lake Huron Committee within the Commission framework provides a mechanism for consideration of problems specific to that lake. The Commission with the assistance of Federal and State agencies engaged in fishery research and management prepared a brief entitled "A Prospectus for Investigations of the Great Lakes Fishery," which was prepared in July 1964. Many of the investigations proposed for Lake Huron in this report are contained in that document.

6. Development of a sound fishery management base will require joint consideration of both commercial and sport fisheries. Although exact data are lacking on sport fishing removal, it is generally agreed that it is significant and will become even more so with the proliferation of newly planted exotic species. Under proper management, the interests of both these fisheries are complementary. In the past, and to some extent currently, needless parochialism has hindered long-range management.

The regulatory program is a complex and controversial problem which requires special consideration in future years. The magnitude of past and present regulatory problems have been described previously.

Attempts to foster fishing methods geared to efficient and economic harvesting of abundant, low-priced fish have often been penalized by the regulatory structure. The differing State and International jurisdictions covering the Great Lakes further complicate the problem. To the extent that differences, discrepancies and overlapping of the regulatory structure result from variations in past administrative approaches, remedies can be expected through closer cooperation and coordination among the jurisdictions involved. The mechanism for such cooperation and coordination already exists within a number of organizations, including the Great Lakes Commission, Great Lakes Basin Commission, and the Great Lakes Fishery Commission.

Regulatory problems are for the most part based on various criteria for allocation of the fishery resource. In the past, exploitation of this common property resource has been characterized by a flow of fishermen into and out of the industry depending on the abundance of various species and prevailing prices. Freedom of entry has tended to reduce the profits that a fixed number of fishermen could have made during periods of favorable prices and abundance and thereby reducing available reserves during depressed periods. One of the results of this situation has been the financial inability of many fishermen to undertake the modifications of operation necessary to adjust to changing conditions. An overallocation of resources in the fishery frequently occurs as well. Another effect is the concentration of effort on certain species often to the extent that populations are reduced to a point where water quality and other factors assume critical importance in perpetuating the species.

It appears that many of these problems may be mitigated by the institution of restrictions on the number of fishermen who may legally operate and limitations on the amount of fishing effort. It is recognized that an efficient and equitable program of limited entry poses many complex problems of data collection and management. The wide fluctuations in abundance of many of the more valuable Great Lakes species will seriously hamper allocation of the resource. The matter of dealing with the many part-time fishermen who depend on fishing to provide an important part of their total income is also a problem. Despite these difficulties, some form of limited entry will be established in the near future in the lake trout fishery of Lake Superior and in the State of Michigan waters of Lakes Erie, Huron, and Michigan. Over the long run, a flexible, and equitable system of limited entry managed on an interstate basis will greatly improve the efficiency and viability of the commercial fishing industry while safeguarding the supply of fish stocks.

A sound commercial fishery regulatory program must likewise be coordinated with related regulatory programs such as those for sport fishing and water quality (pollution) control where interests overlap. Little of this has been done in the past and it is questionable whether sufficient reliable knowledge has been available to serve as a basis for effective coordination. For the future, however, such coordination is a definite requirement and should be implemented through the existing mechanisms cited above.

Economic Base. Economic-related problems of harvesting, processing, and marketing became more apparent in the Lake Huron fishery following decline of the highly valued species. The basic orientation of production has shifted from selective harvesting of the larger and more valuable individuals and species to volume production of carp, yellow perch, and suckers. In the relatively competitive markets for these fish much more stress must be placed on efficient methods of operation in comparison with the former fishery.

Relatively little data is available on the economic structure of the fishery other than the basic statistical records which indicate numbers employed, catch, effort and boats and vessels operating. It is clear that the number of full-time fishermen has dropped off markedly--from 184 in 1950 to only six* in 1966. Total employment has not declined to this extent due to the periodic influx of part-time and casual operators when market conditions or other factors indicate fishing will be profitable. In recent years, fishing on Lake Huron has been almost entirely a part-time venture. It also appears that the distribution of landings among fishermen shows a high proportion of the catch and value accounted for by a relatively few operators. This pattern is similar to the other Great Lakes and inland freshwater fisheries.

Undoubtedly, the decline in populations of choicer species due to sea lamprey predation had important economic ramifications for the commercial fishery. In many instances, fishermen have not adapted their methods of operation to changing populations, preferring instead to either wait for better days or leave the fishery. A lack of sufficient capital to undertake the necessary modifications is a factor. Also, increasing industrialization in the Saginaw Bay area has made jobs available usually paying higher wages than can be found in the fishery. As a result, many individuals have reduced their fishing effort to a part-time or seasonal basis, using fishing as a supplementary source of income. On the one hand, it is likely that these part-time operators have only a small investment in their fishing enterprises and could not be expected to make large capital expenditures in modern fishing methods. At the same time, given the methods available, fishing can represent a relatively efficient use of their time in conjunction with other jobs available. In this respect, the average gross income per fisherman on the lake must be reviewed in terms of a predominately part-time income source.

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*The definition of "full-time fishermen" used above is based on the number of operating days and may understate the actual number of fishermen dependent on fishing as their primary income source.

Solutions to these economics-oriented problems involves consideration of a number of inter-related factors. The matter of raising market demand for these species in abundance is undoubtedly a critical aspect. Information is greatly lacking on consumer preferences and price and income elasticities for most freshwater species and for specialty items such as smoked fish and gefilte fish. Economic studies are needed to relate the biological factors of species composition, abundance and stability to the costs and efficiency of various harvesting and processing methods. The possibility of centralized or cooperative processing and marketing facilities should be examined as well. In addition, considerably more data are needed on fishing costs, effort, percentage of income derived from fishing and similar factors before limited entry or similar catch restrictions can be efficiently and equitably imposed. The value of balanced exploitation of available stocks in improving the recreational as well as the commercial fisheries must not be overlooked in achieving maximum social and economic benefits from the Great Lakes fisheries.

In reviewing the economics of harvesting, no significant changes in fishing gear have occurred on Lake Huron during the years of record, with the exception of brief use of the deep trap net during 1929-1935. Gill nets, shallow trap nets, and the haul seine continue to be the primary gear used. A recent development on the Great Lakes has been the use of trawls for taking large quantities of such species as alewives for industrial or animal food purposes. This gear was first used commercially on Lake Michigan in 1959 and by 1967 led to the harvest of about 42 million pounds of alewife. The use of trawls on Lake Huron has not occurred primarily because of the lack of knowledge regarding the seasonal availability of various species and the shortage of suitable trawling areas in the central and northern part of the lake. It is believed that bottom trawling is feasible only in some parts of Saginaw Bay and the lower lake; however, additional study would be necessary to determine the areas involved and the species to be harvested.

The general goal of the Bureau exploratory fishing and gear research program is to find the most economical means to catch each commercial species in each body of water. To learn this, it is necessary to study factors which influence fishing effectiveness, fish distribution, seasonal availability, effects on protected species, and feasibility of various fishing systems. The ultimate objective is to help develop a modern commercial fishery which will be able to easily adjust to changing conditions, management requirements, and socio-economic considerations.

As a base upon which Lake Huron fisheries can be developed in the future, it is necessary to know when, where, and how much of the important commercial species can be harvested from year to year. It is also necessary to know what fishing systems are required and what production rates and production costs will be. Periodic systematic exploratory fishing surveys furnish much of this information, but other research and development activities are equally as important. These activities are aimed at improvement of fishing vessel design in all respects and at discovery of better means of locating, capturing, and handling fish.

Improved processing techniques offer potential economic opportunities for commercial fisheries. Fishery products are an excellent source of balanced animal protein and vital growth factors of significance to human and animal nutrition. Handled carefully and processed properly, they offer desirable variety, as well as an excellent starting material for a spectrum of industrial uses (Borgstrom, 1961, 1962, 1963).

Under conditions prevailing in the historical past, handling and processing were probably adequate for consumer needs and standards of the times. In comparison with recent advances of other segments of the food industry, however, the commercial fishery has fallen far behind in modernization of plants and processing techniques, development of new and improved food products, and quality control and sanitation programs (Stansby, 1963).

A relatively recent trend in the Great Lakes commercial fishery has been the harvesting and processing of fish for pet food and fishmeal (Bureau of Commercial Fisheries, 1962). The industry has been centered primarily on Lake Michigan to take advantage of the large alewife populations and the availability of chubs. A portion of the Lake Erie catch is also marketed as mink feed while little or none of the Lake Huron harvest is sold outside of human food markets.

The development of this industry has been hampered by a number of factors including the lack of efficient means of harvesting such as trawls and a shortage of adequate processing facilities. These two deficiencies are usually inter-related since the production of fishmeal and similar products require sufficient and timely raw fish supplies to maintain equipment in operation. Where the development of harvesting and processing facilities have achieved a degree of integration, production of non-food products has proven feasible.

To increase future industrial consumption, it will be necessary to (1) attain a high level of mechanization in the harvesting and handling of the raw fish (Greig, et al, 1964), and (2) establish manufacturing outlets capable of rendering such raw materials to high-quality, uniform, and nutritious, safe products for animal consumption. Some degree of processing of the raw fish is necessary (Gnaedinger, 1966), such as through a fishmeal or similar type operation. Bureau technologists have been developing such a rendering process which might well be applicable to the needs of the Lake Huron industry. This process renders much of the moisture and oil (containing a large portion of the pesticide residues of the fish) from the raw fish, renders inactive the thiaminase factor (present in many of the Lake Huron species), and yields a press-cake product tailored for direct supplementation of mink diets, or suitable as a more uniform raw material for use in canned pet food production. The "intermediate" press-cake may also be dried to a fishmeal-like product. Preliminary acceptance tests on mink have already been successfully completed for the experimental press-cake. More detailed evaluation of test products as to growth response and effect on reproductive factors (of the mink) are scheduled. The experimentally designed process, has been scaled up to a pilot-size model to permit more adequate feasibility and production tests and economic evaluation.

No dramatic reversal in the availability of traditional "fine-food" species from Lake Huron can be expected at least until the lamprey is controlled. At the same time, it is likely that environmental changes, especially in Saginaw Bay, will tend to increase the abundance of low-valued species. It is possible to upgrade the relative worth of this abundant resource but relatively large catches of fish handled promptly and economically through the harvesting, handling and processing chain will be required.

The greatest need for industry in the area of products for human consumption is a departure from traditional product forms (i.e., the fresh, dressed fish philosophy) to concepts related to modern merchandising practices. Such would include frozen, boneless, skinless convenience items suitable for portion-control type feeding programs (e.g., Individually Quick Frozen (IQF) fillets, portions, cakes, etc., breaded or non-breaded). Of even more consequence would be production of a uniform, boneless, skinless raw material intermediate of a non-comminuted type that could serve for a variety of final or "finishing" product interests. Species identity of the original input would tend to receive less emphasis in this type of production with obvious gains for increased utilization for such common Lake Huron species as carp. Currently mere use of the name invokes automatic consumer resistance.

In recent years, the Bureau of Commercial Fisheries, with the assistance of university researchers and segments of the industry, has developed promising approaches in processing technology. Experimentation and study of means for improving the quality and extending the shelf-life of fresh (Emerson, et al., 1966) and frozen (Greig, et al., 1967) fish products have received considerable attention. For example, Bureau technologists are currently developing techniques to control rancidity development and undesirable color changes in such species as chub, cisco, white bass, smelt, and sheepshead (Greig, et al., 1967; Greig, 1967). New product forms, such as IQF fillets, blocks, and processed portions have been considered as well as related packaging needs. New research is planned on the previously cited potential of a fishery raw material intermediate for carp, sheepshead, and other problem species. Studies are in progress to determine the applicability of pasteurization levels of gamma radiation to extending the refrigerated shelf-life of various Lake Huron species in order to expand the fresh market area for products such as fillets (Emerson, et al., 1966; Emerson, et al., 1965; Kazanas, et al., 1966 Mar.; Kazanas, et al., 1966 Nov.). With the anticipated approval of this process for fish by the Food and Drug Administration, it is expected that marketing channels in the central portion of the United States will begin to handle such products. The Bureau is also exploring other areas: (1) greater mechanization of fish processing and handling (Emerson, 1964); (2) development of smaller portable equipment for fish reduction (Gnaedinger, 1965); and (3) the development of quality and sanitation guidelines as a consequence of extensive microbiological research (Dougherty and Seagran, 1967).

The present depressed state of the industry apparently has discouraged investment in new and experimental approaches for improved fish handling and processing. This failure of the commercial fishery to keep abreast of modern processing technology has been compounded by a variety of problems related to environment and environmental change. These include botulism poisoning outbreaks (Lewis and Cassel, 1964; Petaschuk, et al., 1964) and the increasing evidence of pollution (especially pesticide and insecticide residues in fresh-water fish).

Just as water supply engineering must provide chlorination to supplement basic efforts to obtain pure water in the first place, so fish processing technology must provide sufficient protection and remedial procedures to maintain a safe and marketable product. As an example, Bureau of Commercial Fisheries technologists in the course of developing smaller, more efficient fish reduction processes (Gnaedinger, 1965; Gnaedinger and Krzeckowski, 1966), have developed various products which contain significantly less fish oil than the corresponding raw material. This achieves a double objective. The amount of a uniform by-product more valuable to industry is increased, while the oil fraction, in which undesirable residues of pesticides and other harmful chemicals tend to concentrate, is reduced in the product going to the consuming animal.

Defensive technology may be defined as the development of methods and techniques to remedy or offset undesirable and hazardous conditions that interfere with the smooth, safe flow of commercial fisheries products to market. For example, to avoid further outbreaks of botulism poisonings, related to improperly processed or handled fishery products, more basic information on the botulism organism is necessary, such as to what degree and how it is present in the fisheries environment (Bohohm and Graikowski, 1966). How can fishing vessels and particularly processing plants be designed and maintained to minimize the occurrence and carry over of this and other pathogens to the final product (Dougherty and Seagran, 1967)? What are the important biochemical characteristics of these pathogens which, if better understood, would permit the design of more effective processing and sanitation protocol (Christiansen, et al., 1968; Weckee and Wasje, 1966; Bratzler and Robinson, 1967) to eliminate their occurrence in products reaching the consumer--even if the products are mishandled? The answers to these and other questions concerning Clostridium botulism arethe basis for an intensive research program currently underway by the Bureau of Commercial Fisheries in cooperation with State agencies and university staffs. This research gives promise of resolving the basic botulism problem if adequate control and regulatory measures are forthcoming from the governmental agencies involved.

Other areas of defensive technology are being pursued. For example, extensive microbiological knowledge of the commensal spoilage flora (Kazanas, et al., 1966 Nov.) associated with Lake Huron fish has already been obtained, including knowledge of the principal sites of contamination where additional flora contaminate the product as fish are handled and processed (Bureau of Commercial Fisheries, Technology Laboratory, unpublished data). Such information is of importance in designing effective plant sanitation programs and product quality standards. In addition, better knowledge of the chemical composition and related process-induced changes occurring in freshwater fish are being obtained, which will assist in controlling adverse flavor, odor, and color changes in processed products. Some of these changes are apparently closely related to the chemical make-up of the fishery material, which in turn is affected by the nature of the fishery environment and its relative state of degradation by pollution and other factors.

The Lake Huron Basin had 1,200,000 people in 1960 and this is expected to reach 3,300,000 by 2020. When the basin's location with respect to the populous midwestern urban center is considered, the market potential for fishery products is obvious. However, full realization of this potential has been limited by lack of quality control; concentration on fresh forms rather than processing for the packaged frozen market; high unit costs of shipping small lots of fish; and the rising volume of imports of the more desirable species.

For several of the major species landed in Lake Huron, especially walleye, catfish, and whitefish, demand has held at a high level for many years. For other species such as yellow perch, white bass, chubs, and sheepshead, the market is extremely competitive and often unstable because these species are relatively abundant and easily harvested in most of the Great Lakes. It is often the case that markets for these species are periodically glutted and prices drop off as a consequence. Yellow perch in particulr are aggresively marketed by Canadian fishermen and often packed in more convenient frozen and breaded forms. The smoked chub market on the east coast, a major outlet for the Great Lakes fishery, collapsedafter the botulism incidents of 1962. Although demand has gradually risn, there are still frequent periods of oversupply of chubs.

Carp, ranked second in punds landed on Lake Huron, has been subject to a gradual price declie since the early 1950's. On the average for all grades, this decine has not been substantial but whereas formerly the smaller sizd carp could be marketed all year, now there are months where no market at all exists for these sizes. Thus, in 1957 wholesale prices for medium carp were at least four cents per pound during all 12 months and jumbo grades brought up to 14 cents in September and December In 1965, no market existed for mediums between January and August and prices were three cents while the top price paid for jumbos was eight cents.

In general, the demand for the highly valued species in relatively limited supply has been maintained while consumption of less desirable species has declined with substitution of inexpensive meat products and the de-emphasis of eating fish as a religious custom. At the same time it has been only recently that freshwater species have been processed and distributed in the convenient packaged forms which have characterized marine products since the end of World War II. It now appears that a more integrated harvesting-processing-marketing arrangement is necessary in order to compete with other fishery and animal products. The organization of such enterprises will require coordinated efforts of the industry itself with the encouragement and assistance of State and Federal agencies. This active governmental assistance is a key ingredient and probably accounts for much of the recent growth in Ontario's Lake Erie commercial fishery while the U. S. catch and earnings have been declining.

Improvement in two general marketing areas would provide considerable impetus to the commercial fishing industry:

1. Marketing Research. Detailed information is not available on the market areas and consumer segments for these species abundant in Lake Huron. Data should be developed to meet these needs including

the identification of species distribution and preferences among geographic areas and ethnic and income groups.

2. Market Development. This involves both intensification of consumer education through mass-information media, selective emphasis on specific consumer groups and agressive development of new outlets for Lake Huron fishes, especially the lower-priced species. There has been some recent expansion of such marketing outlets in the fields of animal food, fishmeals, and fish oils in the Great Lakes area, primarily on Lake Michigan. The economic feasibility of large scale production of fishmeal and fish oil from freshwater species has also been established. In addition, a firm on Lake Superior has been successful in test marketing attractively packaged, frozen fish (herring and chubs) produced by relatively modern processing methods.

The present method of collecting and summarizing data on the catch and effort of the commercial fishery has proven satisfactory and should be continued. This system of statistical compilations should, however, be kept under continual review to assure sound interpretation and adequacy of procedure as fish stocks and fishing methods change. Particular attention must be given to the possible influence or gear modifications, fishing regulations, and economic factors on the statistics.

Knowledge of the amount of the sport fishery production is becoming increasingly important for management of the total fishery resource. Recent estimates indicate that the annual catch of some species by anglers may exceed several million pounds and that the sport fishery is a major user of the resource in certain areas. Data on the sport fishery and the commercial catch statistics will provide figures not previously available on the total production of the lakes. The field checking of statistical sampling of the sport fishery may be coordinated with the collection of biological information on the sport catch, or carried out as a joint project.

In summary, the basic economic problems of the fishery will be solved by focusing on the modernization of the industry, making it responsive to changing consumer requirements and needs while facing a dynamic resource environment and species base. This requires greater research effort, promotional activity, quality control, and cooperation among government, industry, universities, and the private sector. In addition to the detailed requirements previously enumerated, at least two programs are suggested which could provide an immediate impetus for focusing on these problems. These are:

1. Establishing of an integrated harvesting, processing and packaging operation in the Saginaw Bay area for yellow perch production to take advantage of the abundant stocks of this species. Development and financing of this facility should be largely the responsibility of private interests, although governmental assistance should be made available for technical and organizational advice.

2. Establishment of a pilot commercial fish processing plant within the Lake Huron Basin to bridge the gap between the promising experimental innovations for utilizing abundant stocks of low value fish other than perch and implementation of self-sustaining commercial operations--again with such governmental aid as may be appropriate.

SPORT FISHERIES

Species. The State of Michigan has been endowed with diverse water supplies that provide a wide range of fish species. The more important sport fishes of the Lake Huron Basin are listed in Table 11.

Table 11. Important Sport Fishes of the Lake Huron Basin

Common Name	Scientific Name
Lake trout	*Salvelinus namaycush* (Walbaum)
Rainbow trout	*Salmo gairdneri* Richardson
Brown trout	*Salmo trutta* Linnaeus
Brook trout	*Salvelinus fontinalis* (Mitchill)
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Northern pike	*Esox lucius* Linnaeus
Muskellunge	*Esox masquinongy* Mitchill
Channel catfish	*Ictalurus punctatus* (Rafinesque)
White bass	*Roccus chrysops* (Rafinesque)
Rock bass	*Ambloplites rupestris* (Rafinesque)
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)
Bluegill	*Lepomis macrochirus* Rafinesque
Smallmouth bass	*Micropterus dolomieui* Lacepede
Largemouth bass	*Micropterus salmoides* (Lacepede)
White crappie	*Pomoxis annularus* Rafinesque
Black crappie	*Pomoxis nigromaculatus* (LeSueur)
Yellow perch	*Perca flavescens* (Mitchill)
Sauger	*Stizostedion canadense* (Smith)
Walleye	*Stizostedion vitreum vitreum* (Mitchill)
Blue pike	*Stizostedion vitreum glaucum* (Hubbs)
Smelt	*Osmerus mordax* (Mitchill)
Sturgeon	*Acipenser fulvescens* Rafinesque

Investigations by Bureau of Commercial Fisheries scientists indicate that a number of species important to the sport fisherman and inhabiting Lake Huron are not as abundant as during the pre-lamprey period. This finding adds additional credence to the need for an intensive lamprey control program in Lake Huron.

The distribution of some of these species is briefly described as follows:

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Yellow perch. Distribution is statewide. In terms of numbers taken, it is the most important sport fish caught in northern lakes and the coastal waters of Lake Huron.

Walleye. Abundant in Lake Huron and Saginaw Bay. Large spawning runs occur between Lake Huron and the tributary systems.

Northern pike. Abundant and widely distributed in the state. The species is generally rare in Lake Huron, except in bays and connecting waters.

Muskellunge. Found in Lake Huron and a few large inland lakes closely connected with Lake Huron. Also abundant in the Indian River-Cheboygan River system.

Bluegill. Abundant in inland lakes of southern Michigan and locally abundant in lakes of the Upper Peninsula. This is the most important game fish in southern Michigan.

Black crappie and white crappie. Common in lakes of the southern half of the Lower Peninsula. Less abundant in the Upper Peninsula.

Largemouth bass. Abundant in lakes throughout the Lower Peninsula. Common in weedy bays and protected shoreline areas of Lake Huron.

Smallmouth bass. Distribution is statewide. It is most abundant in larger lakes with open shoals and gravelly or rocky bottoms. Also abundant in rocky shore areas of Lake Huron.

Smelt. Unpredictably abundant to sparse in Lake Huron and tributaries.

Brook trout. One of two trout native to the State of Michigan. Abundant in many streams in the northern two thirds of the State. Common in some streams in the Lower Peninsula and in some smaller lakes in the Upper Peninsula. It is rare in Lake Huron. Brook trout are widely stocked to support lower quality trout streams.

Brown trout. Most common in streams of the northern half of the Lower Peninsula, but rare in inland lakes and Lake Huron. It is widely distributed through stocking.

Lake trout. Uncommon to rare in Lake Huron at the present time.

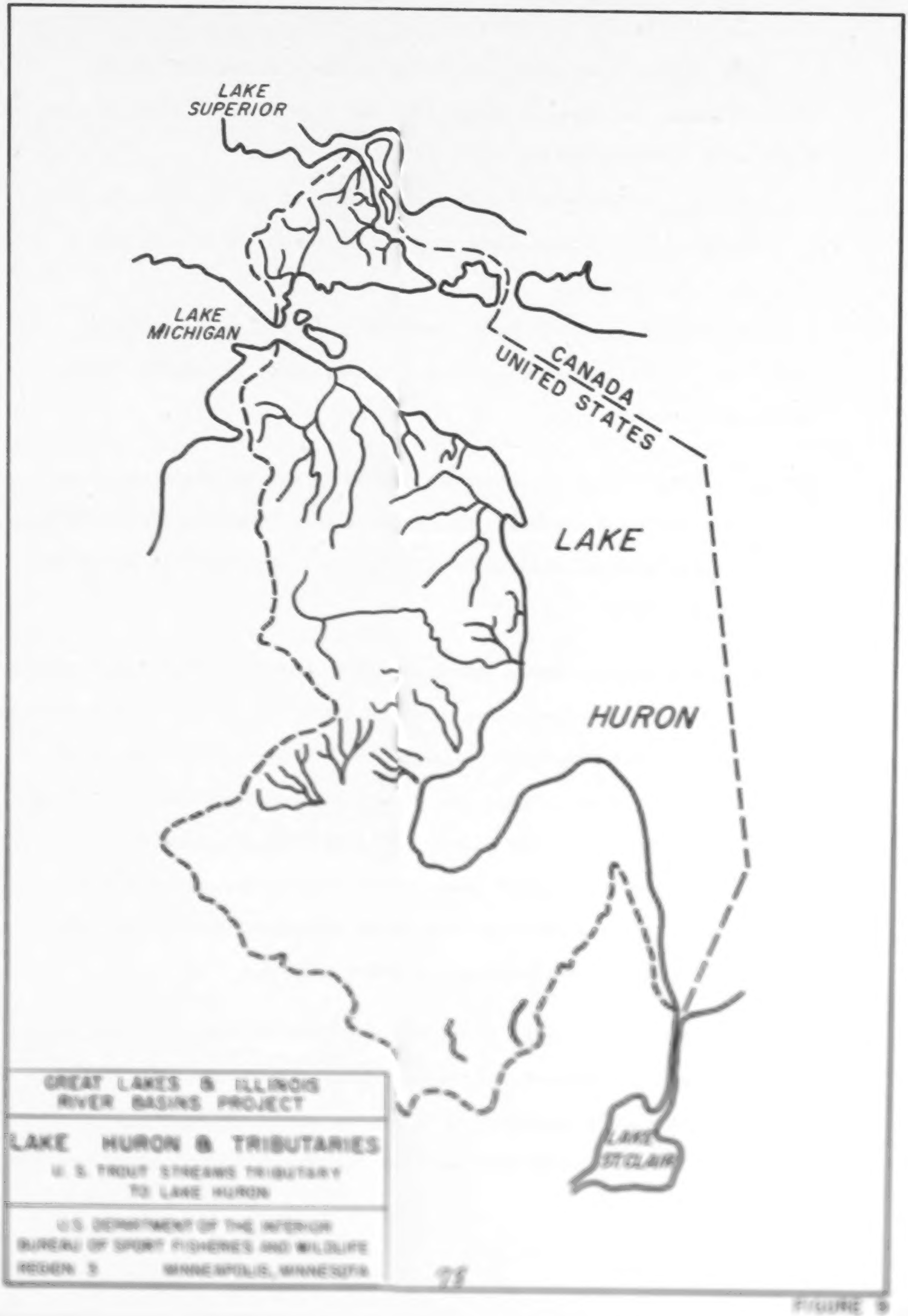
Rainbow trout. Common along most of Lake Huron, using many of the tributaries for spawning.

Lake Sturgeon. Prefer large lakes and rivers. Sturgeon spearing in Michigan is confined almost wholly to Black, Burt, and Mullett Lakes during the winter.

Habitat. Basin fishery resources are limited by natural restrictions of the habitat available to them. For the purpose of this resource discussion, the Lake Huron drainage will be examined by the fishery habitat available in various subbasins.

The Cheyboygan River subbasin (Figures 8 and 9) has two famous trout streams within its boundaries--the Pigeon River and the Sturgeon River. This subbasin also includes several trout lakes, the most important of which are Burt and Mullett Lakes. Pigeon and Sturgeon Rivers support brown trout and brook trout. Sections of the Pigeon River have been set aside by the Michigan Department of Natural Resources for fishery research purposes. The Department is experimenting with changes in regulations and stocking programs in an effort to find ways to improve fishing.

The Inland Waterway, located in the Cheboygan River subbasin, is an extensive system of lakes and connecting rivers which empty into Lake Huron. The Waterway, about 1,600 square miles in area, is one of Michigan's more important fishing centers. The area is well known for its fishing, including


LAKE SUPERIOR
LAKE MICHIGAN
CANADA
UNITED STATES
LAKE
HURON
LAKE ST.CLAIR

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
U. S. TROUT STREAMS TRIBUTARY
TO LAKE HURON

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 9

walleye, sturgeon and muskellunge. Walleyes are present throughout the system, with the exception of Douglas and Pound Lakes (Crowe, 1958).

The St. Marys River, and other Upper Peninsula streams have cold-water environments which provide good trout habitat. Most Upper Peninsula streams also provide good smelt fishing in season.

In the Lower Peninsula, portions of the Thunder Bay River have cold-water environments providing good trout habitat. Fletcher Pond, a 9,000 acre lake on the South Branch of the Thunder Bay River provides good northern pike fishing. Catch limitations have been necessary in order to increase average size and quality of the pike.

Few trout fishermen have not heard of the famous AuSable River in north-central Michigan. The upper reaches of the AuSable are used by more fishermen and canoeists than any other river in the State. A 1962 creel census study on the Main AuSable, South Branch AuSable, and North Branch AuSable showed that canoeists and anglers spent more than 16,000 hours per mile of stream (Alexander and Shetter, 1966). Historically, fishing has always been excellent in the AuSable. Sturgeon and grayling were abundant in the river in the 1800's. During that period, the grayling became so famous that the local residents of Crawford, Michigan, re-named their town Grayling, Michigan. Grayling became scarce by 1893 and eventually disappeared by 1915. Changing ecological conditions and trout introductions were responsible for the grayling reduction. Aside from the loss of sturgeon and grayling, the modern day AuSable still produces good catches of trout, particularly brook and brown trout. Considerable fishing is done along the jetties at the mouth of the AuSable (Photo 1). Habitat conditions for trout are relatively undisturbed in most of the river. Housing developments and summer cottages have encroached on some sections of the river, to the detriment of fishing.

Photo 3. Breakwalls at the mouths of rivers are used by fishermen. This breakwall is at Oscoda, Michigan, at the mouth of the famous AuSable River.

The AuGres River drainage is close to population centers in southeastern Michigan and, therefore, receives heavy angling pressure. The most important fish in the AuGres River are the lake-run rainbows. In addition to the rainbow trout, the watershed streams include brown trout and native brook trout. Sea lampreys and several minor nongame species are also present. Although most of the river and its tributaries provide good trout habitat, some stretches on the East Branch AuGres have been adversely affected by highway construction. Angling pressure on trout in the AuGres is heavy. A report on the AuGres fishery recommended some fishing restrictions because of this pressure and because of problems imposed by sea lampreys (Shetter, 1965).

The Rifle River was once considered one of Michigan's finest trout streams. Poor watershed management practices have damaged the fishery severely. A survey of the drainage area in 1941 by the Institute for Fisheries Research revealed that the trout population had become marginal because of adverse conditions in the watershed. In an effort to improve watershed conditions, the Rifle River Watershed Development Program was initiated in July 1950. Since 1950, watershed and stream improvement and trout stocking have markedly improved fishing conditions for both brown and brook trout. Several inland lakes in the Rifle River drainage area are open to the public. They are also used by the State of Michigan for research on ways to improve fishing. These lakes provide both cold-water and warm-water fishing.

The Pine River Watershed (Alcona and Iosco Counties) is located in the northeast portion of the Lower Peninsula. A watershed survey report, completed for the Pine River in 1961, described existing fish populations occurring in the Pine River, its tributaries, and several lakes in the watershed (Michigan Department of Conservation, 1962). Forage fish, including sculpins, darters, dace, suckers, etc., were predominant in the fish population of the Pine River. Brook, brown, and rainbow trout are well represented, with brook trout predominating. Warm-water species in the Pine River Watershed are primarily panfish, plus a few largemouth or smallmouth bass. Fishing pressure on the trout population is extremely heavy. It stems largely from the nearby resort area. Van Etten Lake, the largest lake in the Pine River Watershed, appears to be a reservoir for adult breeder trout. The lake also provides good warm-water fishing for northern pike, bluegills, yellow perch, largemouth bass, and white crappies. The lake is one of the few inland lakes in Michigan with white crappies.

The Shiawassee, Tittabawassee, Flint, and Cass Rivers in the Lower Peninsula have typically warm-water fish populations. Most important species taken are the northern pike, smallmouth bass, rock bass, yellow perch, and walleye. Fishing success in these streams is only fair, due to adverse water quality.

The majority of fish taken along inshore areas in Saginaw Bay are warm-water species. Fishes inhabiting inshore zones include the walleye, northern pike, yellow perch, smallmouth bass, and rainbow trout. Occasionally muskellunge are caught. The walleye is much sought after by both sport and commercial fishermen.

The smallmouth bass is probably the most important game fish in the outer areas of the bay, and is definitely the most important in Lake Huron. Rainbow trout are also taken in the outer bay. Little is known about fishing pressure on the rainbow trout, either in Saginaw Bay or Lake Huron, but they are an important constituent in the catch.

Angler Use. The activities of sport fishermen are not nearly as well documented as Great Lakes' commercial fishery functions. However, the number of anglers fishing Lake Huron and its drainage area in 1960 has been estimated at 240,000. Estimates also indicate that sport fishermen use Lake Huron drainage waters approximately 20 days per year, resulting in an estimated annual angler-day usage of 4.8 million in 1960.

Statewide, the number of fishermen has been steadily declining. Between 1951 and 1964 the percentage of the population that fished declined an average of 2.6 percent annually. A recent publication by the State of Michigan (Department of Natural Resources) listed several factors contributing to the continuing decline of fishing interest. Among the factors were: competition between fishing and other water-use activities such as boating, etc., the urban sprawl, lack of fishing opportunity in metropolitan areas, and others. Data from the state report indicated that a further decline of 36 percent in fishing license sales could be expected by 1980, if present trends continued (Michigan Department of Conservation, 1966).

This statewide trend can be reversed, however, through expansion of fish planting of exotic species, increasing access to underutilized areas and by restoration of polluted lakes and streams to acceptable levels of quality. The coho salmon is a good example of a successful new species of fish in Lake Michigan. Indications are good that Lake Huron could also establish a coho population. Several other desirable species are under consideration by the Michigan Department of Natural Resources. Increased access will expand opportunities for more fishermen. Effective pollution abatement programs are needed in some areas to restore sport fishing to its former level.

Trends cited for angler-use within the entire State of Michigan are not entirely representative of Lake Huron drainage waters. Within this area the urban influence is not as pronounced, nor are the problems of lack of fishing opportunities of great significance. Data were not available to analyze quantitatively the existing trends of angler-use in the Lake Huron Basin as compared with total state-wide trends.

The 1960 study by the Michigan Department of Conservation indicated angler usage of various categories of water habitat throughout the State of Michigan. Approximately 70 to 80 percent of the anglers interviewed, fish in non-trout waters. Studies also indicate that trout fishermen make up less than 17 percent of the total fishermen. The sport fishery of the State of Michigan is divided into three primary classifications: trout waters, non-trout waters, and Great Lakes' waters. Michigan studies show that about 75 percent of trout fishing is stream fishing. Streams also provide about 10 percent of warm-water fishing.

Ice fishing for panfish is an important part of the Michigan sport fishery. Creel census studies on Houghton Lake, Roscommon County, revealed that ice fishing pressure almost equalled that of open water fishing. Although primary ice fishing interest is in catching panfish, "dark houses" are also popular in basin waters for the purpose of spearing lake sturgeon and northern pike. Spearing for sturgeon during winter months is confined almost entirely to Black, Burt, and Mullett Lakes in the Black-Cheboygan River system. Construction of dams and advances in agricultural practices have reduced sturgeon populations in these three lakes.

WILDLIFE

Species and Habitat. The white-tailed deer is the most abundant big game animal in Michigan. Before 1850, the Lake Huron Basin was heavily forested and deer populations small. Numerous forest fires from 1890 through 1910 destroyed most of the existing deer ranges and virtually wiped out the herd. Regrowth of vegetation followed and deer herds increased rapidly until they reached a peak in the late 1940's. Since the 1940's, deer numbers have been declining due to reductions in range and food supplies. The present deer herd in the Lake Huron Basin is estimated at approximately 240,000 animals (Michigan Department of Conservation 1967b).

Elk were once native to the State of Michigan, but disappeared during the middle 1800's. Their disappearance was the result of a sequence of events which began with the settlement of the State. In 1918, elk were reintroduced, with releases being made in Cheboygan County. By 1963, the elk herd had increased to about 3,000 animals. This rapid growth in the elk population pointed toward possible range and food shortages. By 1964, elk ranges were overbrowsed and damage to forests and agriculture became evident. In 1964, the Michigan legislature authorized an elk season in an effort to control the size of the elk herd.

The turkey was common in southern portions of the Lake Huron Basin until about 1875. Turkeys are forest-dwelling birds, and their numbers decreased with the increase in logging. By 1900, the turkey had disappeared. In the period 1955 to 1957, turkeys were planted in portions of the AuSable and Thunder Bay drainage basins.

The pheasant is Michigan's most important upland game bird. The first introduction was made in 1895 near Holland, Michigan. Since then, the

the pheasant has become well established and widely dispersed in southern counties of Michigan. There are few pheasants in the Upper Peninsula except for a pocket of birds in southern Menominee County. Distribution of pheasants is closely associated with soil fertility. Pheasants fare poorly in northern Michigan where soils are generally sandy. The pheasant numbers in the "Thumb" area of Michigan have been decreasing because of decreased nesting and winter cover.
Pheasant populations in the extreme southern portion of the basin, particularly Genesee and Saginaw Counties, are steadily decreasing with increased urbanization.

Bobwhite quail are fairly common in southern portions of the Lake Huron Basin. Populations appear related to climatic factors--areas with mild winters supporting the most birds. Quail occur in the Shiawassee, Flint, and Cass drainage basins.

Ruffed grouse are plentiful in Michigan's timbered areas. They prefer young forest cover in association with streams, swamps, or other wet areas. The better grouse areas in the state are in the lowlands of the Upper Peninsula and the northern part of the Lower Peninsula.

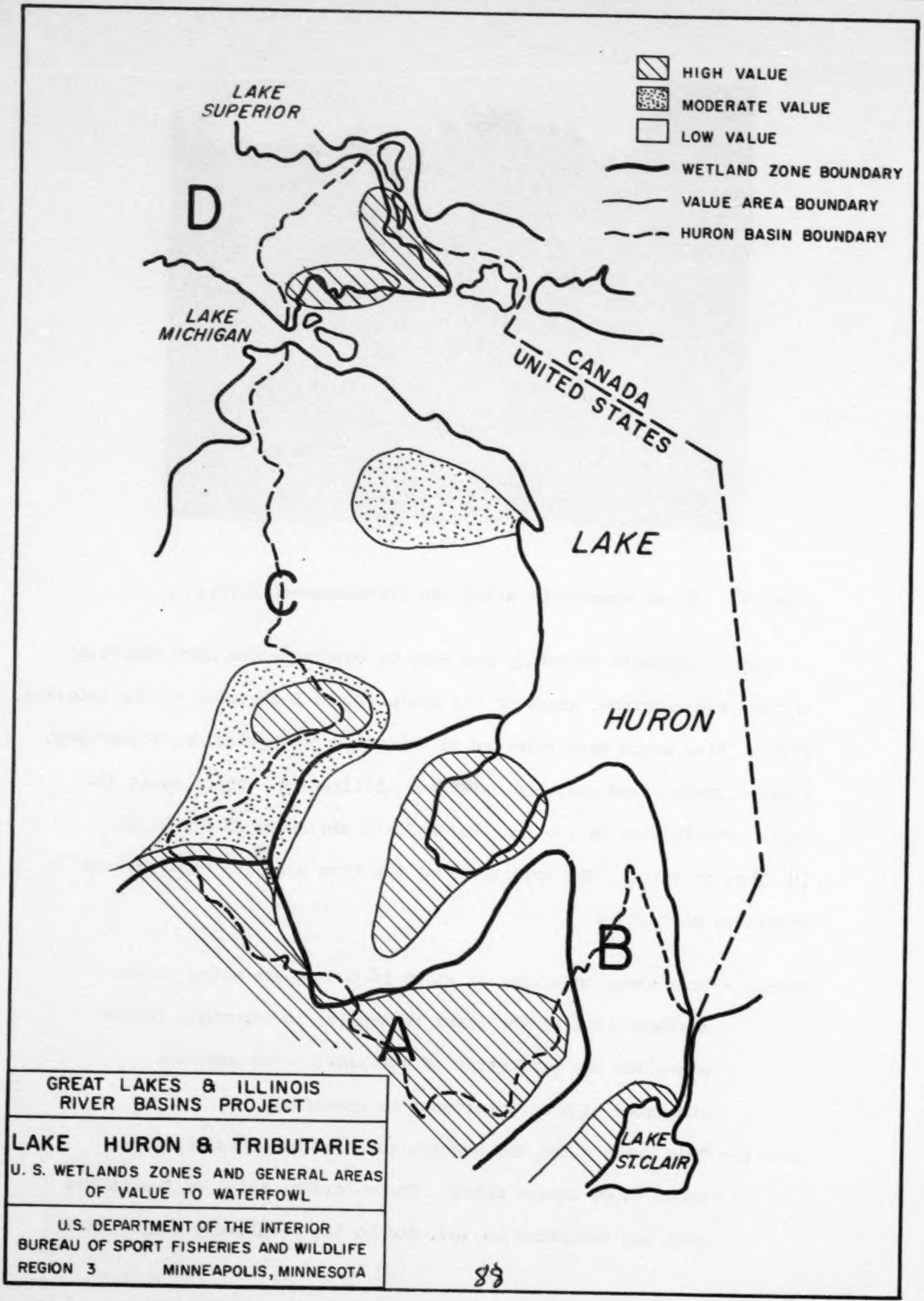
Rabbits provide the most hunting of all small game animals hunted in the basin. They also are harvested in greater numbers than other wildlife species. Most of the better habitat and hunting areas are in the Lower Peninsula in the same range as that of the pheasant (Photo 4). The southern zones of the Upper Peninsula also support good rabbit populations.

Photo 4. Upland game cover along the Tittabawassee River.

In 1955, a wetlands inventory was made to determine the most important wetland and waterfowl areas of the State (U. S. Department of the Interior, 1955). Five zones were selected on the basis of vegetation, topography, soil, climate, land use, and waterfowl utilization. These zones and their contribution to the Lake Huron Basin are shown in Figure 10 (Miller, no date). The importance of the five zones to waterfowl is described as follows:

Zone A - This area, comprised of about 16,000 square miles in the southern half of the Lower Peninsula, is important to the migration and production of waterfowl. The area was evaluated high in importance to waterfowl.

Zone B - This area, along the eastern coast of Michigan, contains about 8,000 square miles. The waterfowl value of the inland zone was evaluated as low, due to the relatively small numbers


▨ HIGH VALUE
MODERATE VALUE
☐ LOW VALUE
WETLAND ZONE BOUNDARY
VALUE AREA BOUNDARY
HURON BASIN BOUNDARY
LAKE SUPERIOR
D
LAKE MICHIGAN
CANADA
UNITED STATES
LAKE
HURON
C
B
A
LAKE ST. CLAIR

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
U. S. WETLANDS ZONES AND GENERAL AREAS
OF VALUE TO WATERFOWL

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF SPORT FISHERIES AND WILDLIFE
REGION 3 MINNEAPOLIS, MINNESOTA

FIGURE 10

L

of wetland areas. However, Saginaw Bay does have substantial importance for waterfowl.

Zone C - This area encompassed the northern half of the Lower Peninsula. It is the largest of all the zones, containing about 17,000 square miles. The zone was evaluated as moderate in importance.

Zone D - This area was designated as the eastern half, about 7,000 square miles, in the Upper Peninsula. The Seney Migratory Waterfowl Refuge is located in this zone and is of high value to waterfowl. The remainder of this zone has moderate to high overall value to waterfowl.

Zone E - The area includes about 10,000 square miles in the western half of the Upper Peninsula. The entire area is rated moderate in value to waterfowl.

Significant numbers of waterfowl winter in Michigan, but the State is not considered as a nationally important wintering area. Depending upon the severity of the winters, approximately 150,000 to 200,000 waterfowl winter in Michigan. The Detroit River area (Lake Erie Basin) is the most important wintering area for diving ducks. Lake Huron Basin waters winter relatively few birds.

Waterfowl species in the Lake Huron Basin are:

- Black Duck
- Mallard
- Blue-winged teal
- Green-winged teal
- Wood duck
- Baldpate
- Pintail
- Gadwall
- Ringneck
- Lesser scaup
- Greater scaup
- Redhead
- Canvasback
- Goldeneye
- Bufflehead
- Ruddy duck
- Blue goose
- Snow goose
- Canada goose
- American merganser
- Red-breasted merganser
- Coot
- Whistling swan

Hunter Use. A recent survey (Michigan Department of Conservation, 1966) indicates that approximately 85 percent of the demand for hunting is generated in the southern third of the State. In contrast, however, game populations and public hunting areas are concentrated in the northern two-thirds of the State. Annual hunting pressure across the State varies from about one hunter per acre to more than 70. Public wildlife areas support the greatest number of hunter-days per acre (Table 12 and Figure 11).

Generally, the percent participation for hunting in Michigan is not keeping pace with the population increase. Many factors are responsible, but rapid urbanization is probably the foremost. Hunting participation in counties of the Lake Huron Basin vary between 13.5% and 36.8%. Both figures are above the national average for this section of the country.

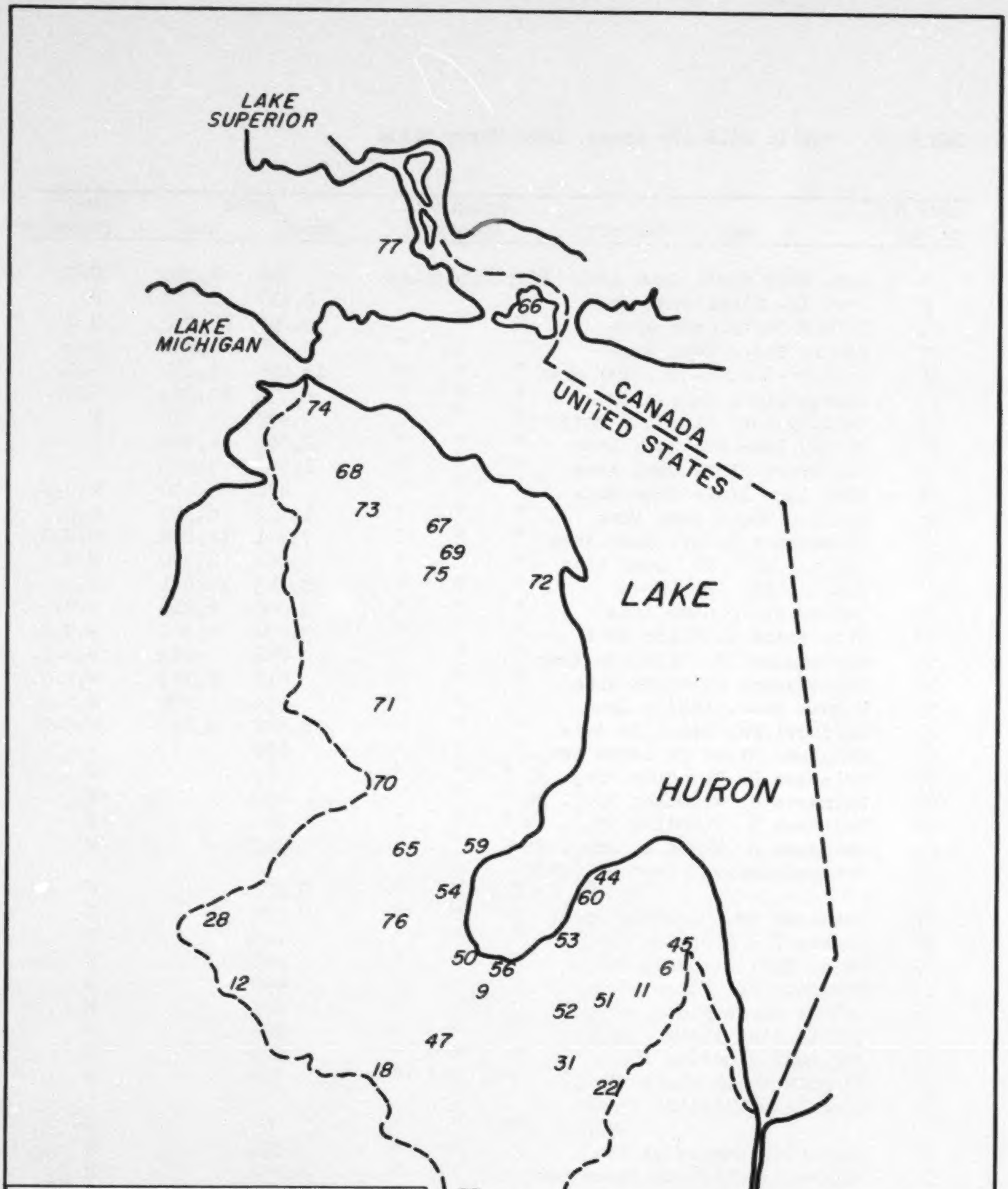
An estimated 140,000 hunters hunt small game in Michigan's Lake Huron Basin counties (Table 13). The number is based on estimated 1964 county populations of people over 15 years of age.

Table 12. Public Wildlife Areas, Lake Huron Basin

Area No. on Map	Name of Project	Management Agency	Acres Owned	Acres Goal	Game Present*
6	Cass City State Game Area	Mich.Dept.Cons.	722	4,010	U.G.
9	Crow Is. State Game Area	" " "	1,157	1,157	W
11	Deford State Game Area	" " "	9,607	18,730	U.G.
12	Edmore State Game Area	" " "	2,358	4,240	U.G.
18	Gratiot-Saginaw St.Game Area	" " "	13,094	31,910	U.G.
22	Lapeer State Game Area	" " "	6,736	12,850	U.G.
28	Martiny Lake Flooding Proj.	" " "	3,467	6,022	W
31	Murphy Lake St. Game Area	" " "	2,560	4,996	U.G.
33	Oak Grove State Game Area	" " "	1,796	3,906	U.G.
44	Rush Lake State Game Area	" " "	470	4,440	W,U.G.
45	Sanilac State Game Area	" " "	1,120	8,320	U.G.
47	Shiawassee R. St. Game Area	" " "	7,741	12,820	W,U.G.
50	Tobico Marsh St. Game Area	" " "	1,694	2,370	W.S.
51	Tuscola St. Game Area	" " "	8,343	10,531	U.G.
52	Vassar State Game Area	" " "	3,048	6,212	U.G.
53	Fish Point Wildlife Area	" " "	3,034	4,521	W,U.G.
54	Nayanquing Pt. Wildlife Area	" " "	842	843	W,U.G.
56	Quanicassee Wildlife Area	" " "	217	1,323	W,U.G.
59	Wigwam Bay Wildlife Area	" " "	136	788	W,U.G.
60	Wildfowl Bay Wildlife Area	" " "	1,542	3,240	W,U.G.
65	Molasses River Flooding Proj.	" " "	850		W
65	Molasses R. Flooding Proj. #1	" " "	83		W
65	Molasses R. Flooding Proj. #2	" " "	200		W
65	Molasses R. Flooding Proj. #3	" " "	590		W
65	Molasses R. Flooding Proj. #5	" " "	195		W
66	Potagannissing River Wildlife Flood.	" " "	2,220		W
67	Tomahawk Cr. Flooding Proj.	" " "	170		W
68	Stoney Cr. Flooding Proj.	" " "	190		W
69	Rainy Riv. Flooding Proj.	" " "	285		W
70	Robinson Cr. Flood.Proj.	" " "	490		W
71	Connor Marsh Flood. Proj.	" " "	225		W
72	Devils Lake Flood. Proj.	" " "	900		W
73	Dog Lake Flooding Proj.	" " "	520		W
74	Dingman Marsh Flood. Proj.	" " "	750		W
75	Sage Lake Wildlife Flood. Proj.	" " "	87		W
76	Kawkawlin Waterfowl Proj.	" " "	590		W
77	Munuscong Wildlife Flood Proj.	" "	4,252		W

* W-Waterfowl, U.G.-Upland Game, S-Shorebirds

Courtesy Michigan Department of Conservation 1967d


LAKE SUPERIOR
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LAKE MICHIGAN
CANADA
UNITED STATES
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LAKE ST. CLAIR

GREAT LAKES & ILLINOIS
RIVER BASINS PROJECT

LAKE HURON & TRIBUTARIES
PUBLIC WILDLIFE AREAS IN BASIN
(SEE TABLE 12 FOR NO. KEY)

U.S. DEPARTMENT OF THE INTERIOR
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FIGURE 11

Table 13. Estimated Number of Hunters by Subbasin, Lake Huron Basin, Michigan - 1964

Subbasin	Estimated Number of Hunters
St. Marys & Tributaries	6,100
Cheboygan	2,800
Thunder Bay	5,700
AuSable	5,800
Tittabawassee	16,500
Shiawassee	28,600
Flint	50,000
Cass	13,800
Saginaw	13,700
Total	143,000

The 1966 Michigan survey revealed that the average annual number of days of small game hunting per hunter varies greatly between various areas of the State. The Upper Peninsula, with 17.2, was highest in 1964, followed by the northern Lower Peninsula with 15.1 and the southern Lower Peninsula with 9.6 days. Using 1964 data from Michigan, total small game hunter days in Lake Huron Basin counties was estimated at 1.1 million.

Prior to 1895, Michigan had no restrictions on deer harvest. Since that date, various restrictions have appeared. These include setting of seasons, closing of selected areas, license requirements (1895), bag limit, special seasons, and many more. For many years, counties on southern Michigan were closed to deer hunting for a variety of reasons. None of the Upper Peninsula counties have ever been closed (Michigan Department of Conservation, 1966b). Beginning again in 1948, statewide deer hunting has been in effect.

Prior to organization of the Michigan Department of Conservation in 1921, deer kill data was unreliable. Since then, good estimates of the Michigan deer herd and good data on kill have become available. An estimated 250,000 hunters hunted deer in counties of the Lake Huron Basin in 1966. Approximately 43,000 deer were harvested. Annual harvest for the basin generally ranges between 40,000 and 50,000 deer. Assuming that bow hunters and gun hunters spend approximately the same number of days hunting, the total annual deer hunting effort is estimated at about 2,125,000 hunter days.

The first managed elk hunt in Michigan history took place in 1964. Prior to that time "elk-looking" was primarily a tourist attraction. Of 298 licensed elk hunters in 1964, 269 were successful. In 1965, 298 licensed elk hunters shot 183 elk. Hunters were permitted to shoot bulls, cows, or calves. Continuation of elk seasons will depend upon the condition and number of elk in the herds.

A five-county area (2,782 square miles) of northeastern Michigan has a population of approximately 1,300 wild turkeys. This census was taken in the winter of 1968-1969. This flock had built up to 800 by 1967, and in the first season that fall 500 permits were issued and 29 turkeys taken. In the fall of 1968 the same number of hunters bagged 43 turkeys. A spring gobbler season is set for two 4-day periods in May 1969. A total of 1,600 permits will be issued (Douglass, personal communication).

There is extensive hunting pressure on the pheasant in southeast Michigan. This includes the "Thumb" portion of the Lake Huron Basin, an area which attracts large numbers of hunters from outside the Basin. During the 1940's and 1950's approximately 200,000 hunters hunted pheasants in the Basin. Since the 1950's, pheasant numbers in that area have declined drastically and hunting pressure has proportionately decreased. The total pheasant harvest is presently estimated at 100,000 or less per year in the Lake Huron Basin.

Grouse hunters in Michigan's Lower Peninsula shot more than 200,000 birds in 1960. In 1965 the total grouse kill was over 350,000. A good percentage of these birds was killed in the Lake Huron Basin but the specific kill figures are not available. Most Basin hunting occurs in young forests along the northeast shore of the Lower Peninsula.

Rabbits are the number one game species in Michigan. The annual rabbit kill is estimated at 150,000 to 200,000 in Lake Huron Basin. Most rabbit hunting occurs in the agricultural areas of the southern portion of the Lower Peninsula.

Based on 1960 duck stamp sales, the number of waterfowl hunters in the State was approximately 84,000. The 1960 waterfowl kill in Michigan was about 428,000. The Lake Huron Basin had an estimated 7,000 waterfowl hunters who killed approximately 36,000 waterfowl in 1960. The most important waterfowl hunting area is Saginaw Bay. Within Saginaw Bay, Wildfowl Bay is the prime waterfowl hunting site. This area contains approximately 415,400 acres of significant waterfowl habitat. Thunder Bay is also an important waterfowl concentration site, although not of the same magnitude as Saginaw Bay.

FUTURE DEMANDS

Commercial Fisheries. The products ofthe Lake Huron commercial fishery are consumed, to a large degree, outside the Basin. Therefore, analysis of needs cannot be confined to this Basin or even the combined basins of all the Great Lakes. Dependence must be placed largely on national statistics and trends, combined with regional production figures.

Based on these factors, future demand for fishery products from the Great Lakes have been projected to the year 2020 (Table 14). These projections assume a medium population growth, a medium per capita disposable personal income, and an income elasticity of demand for edible fishery products of 0.32. Thus, consumption of edible fishery products is expected to increase on a per capita basis with the rise in disposable income. It is believed that effects of increasing income in the future on consumption of fish will not be offset to the extent they have been in the recent past by other factors, such as declining prices and increasing supplies of poultry, beef and other animal proteins. Also, programs now underway or being considered in the areas of product development, improved marketing and handling, and consumer education are likely in themselves to result in an increase in demand. Projections of consumption of industrial fishery products are also included in the figures for total demand and are based largely on increases in broiler production since the bulk of fishmeal is consumed in that industry.

Table 14. Projected Demand for Fishery Products from the Great Lakes (Millions of Pounds)

Year	Total Demand (Edible and Industrial Products)
1960	104.7
1980	147.0
2000	228.0
2010	303.0
2020	412.5

If Lake Huron is to continue supplying about nine percent of the total U. S. Great Lakes commercial fishery landings, as it has over the five-year period of 1960-64, the above projections indicate a demand for about 13 million pounds from the lake in 1980, 20 million pounds in 2000, and 37 million pounds in 2010. During the period 1960-1964, United States catches on Lake Huron averaged almost six million pounds annually, thus to meet projected demands by 2020, well over a four-fold increase in landings will be required. To meet this need, there is an obvious requirement for study and implementation of all reasonable means (including applicable water quality control) to preserve and enhance the commercial fishery resource.

Sport Fisheries and Wildlife. For the purposes of this report, only cursory efforts were made in estimating future demands for sport fishing and hunting. The present ratios of sport fishermen and hunters to total basin populations were applied to population projections for the year 2020. This method may precipitate considerable error because participants are not presently keeping pace with increasing human populations. Nevertheless, by the year 2020, 600,000 anglers are estimated to fish 13 million days within the United States portion of the Lake Huron Basin. Also, approximately 1.1 million hunters are expected to be afield 9.5 million days in the Basin during the year 2020.

WATER QUALITY ASPECTS

Water quality, in a very broad sense, includes not only those items commonly recognized as directly affecting human well-being but also the entire complex of environmental factors influencing fish and wildlife of Lake Huron. This includes bottom sediments, benthic organisms, and plankton. It is within this framework that fishery and wildlife science and management can make a unique contribution to identification and solution of water quality problems. Some water quality factors directly important to human and industrial water use are relatively inconsequential to many fish, wildlife, and aquatic organisms. However, the effects of subtle, sometime intermittent, changes in water quality are observed in these organisms long before gross, easily-measurable, and plainly-observable effects begin to disturb human affairs. Early investment in studies and search for solutions of water-quality-related fish and wildlife problems has a potential for containing and remedying problems before they reach proportions that constitute a threat to human beings and their activities.

EFFECTS OF POLLUTION ON FISH AND WILDLIFE

The most obvious effects of pollution on a fishery are the massive fish kills that can occur. Fortunately, the Lake Huron Basin has experienced relatively few pollution-caused fish kills. Lowered oxygen levels, destruction of spawning or feeding areas, and disruption of the food chain in some areas can have serious consequences. Each of these impairs the quality of the fishery.

Problems of low oxygen have not been of major importance in the Lake Huron Basin. Lowered oxygen concentrations have been reported for Saginaw Bay. They were caused by the high organic discharge of the Saginaw River. The concentrations recorded in 1956 and reported by the Great Lakes Fishery Commission in 1967 were between 7 and 10 ppm (Great Lakes Fishery Commission, 1967). This level is considered adequate for fish life. Outer areas in the Bay had oxygen concentrations between 9 and 12 ppm.

Loss of fishery habitat, due to pollution, has been of generally minor importance. There are, however, localized conditions such as those at Harbor Beach which have rendered it totally inadequate for fish. Most of the Harbor Beach bottom has been covered by a fine black ooze, which in some areas has considerable depth; such areas give off bubbles of decomposition. Other similar areas, though not as extensive as Harbor Beach, are the Pine River at Standish, Thunder Bay River at Alpena, and Cheboygan River at Cheboygan. Saginaw River pollutants have changed much of the bottom conditions in Saginaw Bay. The fresh-water organisms originally present have been replaced with pollution tolerant organisms which can survive in a mud habitat. Fish spawning has been largely eliminated from the area.

Predator species are dependent on their natural food chain. This chain is made up of numerous organisms, each dependent on other smaller organisms, on organic matter, and the sun. The system can be upset by sudden changes in the aquatic habitat. This destroys one or more of the organisms in the chain, thereby eliminating those species further along the chain.

Any of several forms of pollution can create this problem, such as have occurred on several of the Saginaw River tributaries and near the mouth of the rivers previously mentioned. The entire length of the Saginaw River now supports only a very few of the more pollution tolerant species of fish. Changes of water quality and bottom characteristics from early logging operations on the AuSable River were responsible for the disappearance of the grayling (USDI, 1966).

Trout are especially vulnerable to the various types of pollution. Acceptable ranges of tolerance for temperature, habitat type, and food organisms are very stringent. Once trout habitat has been lost, restoration is very difficult. The effects of erosion and subsequent siltation, together with loss of streambank cover combine to produce high temperatures and unsuitable trout habitat. In the Lake Huron Basin, some streams that were originally trout streams now have trout only in the cleaner, headwater areas.

High turbidity has created problems for fisheries in some parts of the basin, notably in the southern half where clay soils predominate. Turbidity may be a direct result of erosion or it may be brought about by various types of pollution. Light penetration decreases and water temperature increases, causing various changes in species composition in the affected waters. Average depths of secchi disc readings in 1968 for Harbor Beach were four feet in the harbor area and sixteen feet outside the breakwater (Michigan Department of Conservation, 1967).

The high turbidity in the harbor areahas reduced light penetration significantly. For comparison, the Great Lakes have readings generally ranging from 14 feet for Lake Erie to 32 feet for Lake Superior. Lake Huron averages about 30 feet (Beeton, 1965).

Species dependent upon spawning runs up tributaries of Lake Huron have a special problem. A single source of pollution dumped into one of these streams can effectively block upstream movements. This type of pollution problem has occurred on the AuSable, Thunder Bay, Pine, and Cheboygan Rivers.

The effects of pollution on the fishery are not restricted purely to physical effects on aquatic life. Fishermen can see, smell, or taste the results of pollution. The sight and smell of dead fish, decaying algae, or litter covering the shores of lakes and streams render these areas unattractive. In addition, any fish taken may not be fit to eat.

Tainting of fish, both odor and taste, have long been the cause of complaints from sport and commercial fishermen on Saginaw Bay. An investigation of these complaints was conducted in 1943. Several of the fish samples from the southern half of Saginaw Bay had unpleasant odor or taste and were unpalatable (Michigan Department of Conservation, 1943). Another investigation was carried out in 1963 involving fish near the city of AuGres. Source of this problem was the Saginaw River. These waters concentrated in a popular ice-fishing pool near AuGres. Results of this investigation also revealed fish with unusual odors and taste.

Litter is a common problem in many of the basin waters. The AuSable River, one of the best trout streams and canoe streams in the nation, is cleaned annually by organizations such as Boy Scouts and FFA from Grayling, Michigan or other nearby towns (USDI, 1966).

Since the early 1890's Michigan conservationists have urged the setting aside of wildlife lands, particularly wetlands, to preserve this important natural habitat. With the increase in agricultural drainage in the 1930's, millions of acres of wetlands were destroyed. By 1957 only about three million acres of wetlands remained. The quality of the wetland habitat is affected by many complex factors, including draining, industrial and/or urban use, filling, dredging, agricultural, domestic, and industrial wastes, and the indiscriminate use of insecticides and herbicides. These activities result in disruptions to or elimination of the food chain. The result is that various wildlife species are forced out of their wetland homesites as surely as though these areas had been drained.

Indiscriminate dumping of wastes, oil, trash, and garbage from commercial and recreation watercraft has markedly increased in recent years. Oil deposits and their effect on shoreline habitat are of increasing concern to wildlife biologists. Saginaw Bay has received more attention regarding effects of oil pollution on wildlife than any area in the Lake Huron Basin. Waterfowl have been seriously affected by adverse water quality. The problem is compounded by the large concentrations of waterfowl in the Saginaw Bay area where there is gross pollution of the water. Oil pollution from vessels engaged in commercial navigation and harmful bottom sediments are characteristic. The oil problem has become progressively more important, due to increased vessel traffic and use of oil for fuel by almost all vessels coming into the Great Lakes via the St. Lawrence Seaway.

In review of these problems, the National Multiagency Oil and Hazardous Materials Contingency Plan was adopted in September 1968, and to that fact regional offices of Federal Water Pollution Control Administration are developing Regional Contingency Plans. A number of resource-oriented agencies are cooperating to provide an early warning system designed to combat potentially disastrous results of spills such as oil and chemicals.

Almost annually since 1961, waterfowl mortalities have occurred in Saginaw Bay area from type "C" botulism. A 1967 report revealed that gulls in Saginaw Bay suffered particularly heavy losses during the summer of 1966. Botulism was the primary cause for the die-off, which ranged from Saginaw Bay northward to Oscoda--a distance of about 80 miles (Michigan Department of Conservation, 1967c). There is indirect evidence that the death of waterfowl from type "C" botulism is related to the increase in alewives in Lake Huron. Carcasses of alewives, consumed by fish-eating shorebirds and waterfowl, provide the media for the growth of the botulism bacteria. Alewives constitute over 50 percent of the diet of gulls on Lake Huron. Waterfowl mortalities from type "E" botulism have occurred during the summer and fall, with considerable mortality at Tawas Point. Summer and fall die-offs were most evident among the shorebirds, gulls, loons, and diving ducks (goldeneyes and American mergansers).

LONG-RANGE TRENDS IN WATER QUALITY

It is difficult to project long-range trends in water quality without an adequate knowledge of historic trends. As pointed out previously in this report, such information is quite limited for the Lake Huron Basin, consisting largely of data available for concentrations of certain dissolved solids over a period of years. These are not necessarily chemicals that are particularly important in terms of their effects on fish, wildlife, and aquatic life at least at existing or projected levels of concentration. They do, however, give a useful indication of what may be happening to other concentrations of more critical water quality items for which accurate, long-term data are not available. Thermal pollution is an item that should be added to this category.

In the open lake there has been a slight but real increase in total dissolved solids, with most of this increase being in concentrations of chloride (3 ppm over 30 years) and sulphate (7.5 ppm over 54 years). Total dissolved solids are low, about 110 ppm, and are more concentrated in Saginaw Bay than in the open lake. In general, concentrations tend to follow the curves for Lake Michigan but with the concentrations at a lower level. There is no evidence of acceleration in the rate of increase of total dissolved solids in the open waters of Lake Huron--in contrast to the well-documented acceleration that has taken place in Lake Erie. An exception is the concentration of chloride, which has exhibited an increase in rate due to the substantial inputs of brine from the Saginaw drainage.

Historical trend data are not available for critical items such as nitrogen, phosphorous, pesticides, detergents, and heavy metals. Current levels of phosphorous of 10 ppb in Lake Huron may be compared with ranges of 49 to 474 ppb in Detroit River water, from 33 to 206 ppb in Maumee Bay, Ohio, and 9 to 22 ppb in the western part of the central basin of Lake Erie. It is likely that concentrations of other critical items have increased at least at the same rate as those for which some long-range data are available, or even at an accelerated rate.

Recent analysis of pesticide concentrations in Lake Huron fish conducted by Bureau of Commercial Fisheries scientists show averages of total DDT (DDT, DDD, DDE) of 2.44 ppm for alewives, 0.75 ppm for smelt, 2.44 ppm for chubs, 2.43 ppm for whitefish, and 1.59 ppm for perch. These concentrations are approximately one-half to one-third those of the same species in Lake Michigan. During the last three years the amounts of DDT in Lake Michigan fish has not changed measurably. If it can be assumed that Lake Huron DDT levels are functions of Lake Michigan outflows rather than wholly originating in the Lake Huron Basin, the equilibrium may hold for the latter lake. Pending accumulation of more data, however, this remains only a supposition.

Dissolved oxygen is usually near saturation or supersaturated at the greatest depths, indicating little or no improvable trend in this critical item. Conversely, oxygen depletion in bottom waters in Lake Erie has been closely related to undesirable changes in fish and aquatic life populations. Dissolved oxygen in Saginaw Bay is generally above 80% saturation but values as low as 66% have been reported. These levels are still adequate for fish and aquatic life. The lack of dissolved oxygen trend data in Saginaw Bay over a sufficiently long period of time to make the trends meaningful makes it difficult to demonstrate these lower levels as clear evidence of the beginning of a decline. It is even possible that in the heyday of the lumbering industry, water quality conditions in certain portions of Saginaw Bay were worse than at present. Nevertheless, considering the relatively rapid flushing rate of the bay, (186 days) the somewhat lower dissolved oxygen levels may well be indicative of a trend that will worsen if remedial steps are not taken.

Except for the Superior Basin, the Huron Basin has exhibited the lowest human population density and the most limited industrial development in the Great Lakes system. This has resulted in a relatively low rate of pollution input into Lake Huron from its own basin, in contrast to the Lake Erie and Lake Michigan situations. There are some localized conditions of degraded water quality such as the innermost section of Saginaw Bay and waters at the mouth of the Spanish River in the North Channel, which no longer support a fishery because of pollution from paper mill wastes. In general, however, the inshore waters of Lake Huron do not exhibit the obvious water quality degradation apparent in Lake Erie and Lake Michigan. Water quality is still high from the standpoint of fish and aquatic life even in these areas which are normally the first affected. Indications of change are apparent through the dissolved oxygen and solids levels of Saginaw Bay, the limited nuisance growths of Cladophora (a filamentous green algae) and the domination of oligochaetes (often a biological indicator of enriched or polluted habitat) in harbor and other inshore areas.

Future population projections that include the Canadian portion of the basin are not available. It is likely, however, that the future growth in the Lake Huron Basin will continue to lag behind that of the three lower Great Lakes. This means that contribution of pollutants from within the Huron Basin will continue to be a relatively small input to the open waters, masked by the massive inflows from Lakes Michigan and Superior. In the absence of remedial measures, however, the water quality situation in Saginaw Bay and other inshore waters may be expected to worsen. The small but indicative changes already discussed may well accelerate on a local basis, reaching the critical point for certain forms of fish, wildlife and aquatic life. Considering the importance of these inshore habitats to the total ecosystem it is essential that the pollution control plan recommended by this study be implemented if the total Lake Huron environment is to be preserved in its general high state of water quality.

Conditions in the open waters of Lake Huron will continue to be largely dependent upon the quality of inflows from Lakes Michigan and Superior for the future period covered by this study. The buildup of total dissolved solids (and other substances for which good long-range data are not available) will continue, slightly behind Lake Michigan trends and diluted by the influx of high quality water from Lake Superior.

Dependent upon what happens in Lake Michigan, this buildup will be at a slow, steady (perhaps almost imperceptible if large-scale controls are effected in Lake Michigan) rate or an accelerated one. More so than any of the other Great Lakes, Huron reflects the fact that, water-quality-wise, the Great Lakes are a system with distant changes being eventually reflected in its aquatic environment.

ENVIRONMENTAL RESEARCH REQUIREMENTS

In order to obtain maximum benefits from an environmental research program and to assure continuity in data collection, there must be adequate coordination and exchange of information. Because fishery agencies have a broad responsibility to maintain harvestable surpluses in existing populations of aquatic life and to contribute to man's understanding and control of aquatic living resources and their environment, it seems logical that these agencies should also have a major role in coordinating and conducting research related to long-term water quality changes. Without proposing any specific institutional arrangements, this function may be exercised through such established mechanisms as the Great Lakes Fishery Commission, where an ecosystem approach encompassing all of the Great Lakes can be adopted.

Specific categories of research requirements include:

1. Monitoring environmental conditions. Continuous measurement and evaluation of basic environmental features are needed to provide the background of information required to interpret and predict fluctuations and trends in fish distribution and abundance. Studies of the environmental conditions in the Great Lakes must extend to their tributaries, to sources of domestic and industrial pollution, and to physical and chemical processes within the lakes which concentrate, add, or remove material. Information from current research relevant to fishery problems should be obtained and evaluated, and additional studies should be undertaken to fill the special needs for fishery inquiry.

As experience revealed the development of stable patterns for certain environmental features, (e.g., certain dissolved solids), work on them could be reduced while the level of monitoring effort on features of critical concern (e.g., heavy metals and pesticides) could be increased. Another area for concentration would be inter-relationships between tributary and inshore environments and fish populations in the open lake. This is closely related to environmental effects on fish populations of engineering projects involving dredging and dumping in these same habitats--another critical area on which little firm information is available. Monitoring efforts would pay particular attention to the effects of heated effleunts from atomic reactors and large power plants.

2. Benthic productivity. Bottom organisms are consumed by almost all fish and aquatic wildlife at some stage of their lives, and the scarcity of certain species may affect the growth and survival of fish significantly. Bottom organisms are also useful indicators of subtle physical-chemical changes in water quality.

The first phase of this work would include studies of the chemistry in and immediately above the sediments. Research would include studies of oxygen demand, oxidation-reduction potential, pH, and the chemical composition of sediments and bottom water. The chemistry of sediment-water nutrient exchange should be worked out to determine if and how nutrients are removed from availability to fish food organisms and how they might be released to increase productivity. Attention should be given also to possible detrimental effects of materials of industrial and domestic wastes (particularly pesticides) on bottom organisms, and the survival of eggs that incubate and hatch on the bottom. Immediate attention should be given to Saginaw Bay.

The second phase would be to determine the mechanisms, rates, and regulating factors of nutrient exchange in bottom fauna production. Surveys should be made to classify organisms and their abundance as to lake depth and sediment type. Laboratory experiments should be conducted to determine the factors of production needed to interpret field observations. This study may point out requirements for monitoring the environment and will contribute materially to studies of fluctuations and levels of abundance of fish stocks.

3. Plankton productivity. Plankton organisms are the most important primary converters of basic energy and nutrients in the deep water areas of the Great Lakes. The amounts and rates of nutrient fixation are the most influential factors in controlling the levels of abundance and potential yield of fish stocks. Thus, the mechanics and role of this system must be measured and understood to provide information needed to predict fluctuations and levels of fish abundance, and to discover means of stabilizing productivity and achieving higher levels of sustained yield.

The initial phase of this investigation should be the development of more reliable sampling gear, especially midwater sampling equipment. Much of the equipment for measuring light, temperature, and for determining the concentrations of major nutrients is presently available, although modifications both of equipment and method may be necessary for problems peculiar to this study.

This work should be coordinated closely with studies on biology of fishes and monitoring the environment. Some field surveys may be conducted in common with studies of bottom fauna.

WATER QUALITY CRITERIA

Future water demands in Michigan will increase faster than the rate of population growth. Much of this increased water demand will have to be supplied from Lake Huron. Fortunately, water quality of Lake Huron is good and future supplies of good water are possible. The increased use of shoreline waters, however, will have direct effects on wildlife species inhabiting these areas. As more people turn to Lake Huron shoreline areas for recreation, the competition to put fish and wildlife habitats to other uses will increase. These demands upon aquatic habitat and water supplies require that standards for water quality be both implemented and enforced in order to safeguard fish and wildlife resources.

A portion of Michigan's water quality criteria for the several uses of water, in conformance with the Water Quality Act (P.L. 89-234), are presented in Table 15. The criteria are those needed to protect fish, wildlife, and other aquatic life. The degradation objective of Michigan's Water Resources Commission is quoted: "Water in which the existing quality is better than the established standards on the date when such standards become effective will not be lowered in quality by action of the Water Resources Commission unless and until it has been affirmatively demonstrated to the Michigan Water Resources Commission and the Department of the Interior that the change in quality will not become injurious to the public health, safety, or welfare or become injurious to domestic, commercial, industrial, agricultural, or recreational or other uses which are being made of such waters, or become injurious to the value or utility of riparian lands; or become injurious to livestock, wild animals, birds, fish, aquatic life or plants, or the growth or propagation thereof be prevented or injuriously affected; or whereby the value of fish and game may be destroyed or impaired, and that such lowering in quality will not be unreasonable and against public interest in view of the existing conditions in any interstate waters of Michigan. Water which does not meet these standards will be improved to meet the standards."

Table 15. Water Quality Standards - State of Michigan*

Fish, Wildlife, and Other Aquatic Life

COLIFORM GROUP
(organisms/100 ml)

The average of any series of 10 consecutive samples shall not exceed 5,000 nor shall 20% of the samples examined exceed 10,000. The avg. fecal coliform density for the same 10 consecutive samples shall not exceed 1,000.

RESIDUES

Floating solids:
None of unnatural origin.
Residues: No evidence of such material except of natural origin. No visible film of oil, gasoline or related materials. No globules of grease.

SUSPENDED, COLLOIDAL AND SETTLEABLE MATERIALS

No objectionable unnatural turbidity, color, or deposits in quantities sufficient to interfere with the designated use.

TASTE AND ODOR PRODUCING SUBSTANCES

Concentrations of substances of unnatural origin shall be less than those which are causing or may cause taint in the flesh of fish or game.

DISSOLVED OXYGEN
(mg/l)

At the average low river flow of 7-day duration expected to occur once in 10 years the following DO values shall be maintained for:
Intolerant fish - warmwater species: Average daily DO not less than 5, nor shall any single value be less than 4.0
Intolerant fish - cold-water species: Not less than 6 at any time.
Tolerant fish - warmwater species: Average daily DO not less than 4, nor shall any single value be less than 3.

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At greater flows the DO shall be in excess of these values.

TOXIC AND DELETERIOUS SUBSTANCES

Not to exceed 1/10 of the 96-hour median tolerance limit obtained from continuous flow bio-assays where the dilution water and toxicant are continuously renewed except that other application factors may be used in specific cases when justified on the basis of available evidence and approved by the appropriate agency.

TOTAL DISSOLVED SOLIDS

Standards to be established when information becomes available on deleterious effects.

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*From Water Quality Standards for Michigan Waters. State of Michigan Water Resources Commission. Department of Conservation, Revised June 1967.

(continued on next page).

Table 15. (continued) Water Quality Standards - State of Michigan*

Fish, Wildlife, and Other Aquatic Life

TEMPERATURE - °F

	Ambient	Allowable Increase	Max. Limit
Intolerant fish, cold-water species	nat. 32° to max.	10°	70°
Intolerant fish, warm-water species	32° to 35°	15°	
	36° to nat. max.	10°	85°
Tolerant fish, warm-water species	32° to 59°	15°	
	60° to nat. max.	10°	87°

NUTRIENTS

Nutrients originating from industrial, municipal, or domestic animal sources shall be limited to the extent necessary to prevent the stimulation of growths of algae, weeds, and slimes which are or may become injurious to the designated use.

HYDROGEN ION (pH)

Maintained between 6.5 and 8.8 with a maximum artificially induced variation of 1.0 unit within this range. Changes in the pH of natural waters outside these values must be toward neutrality (7.0).

RADIOACTIVE MATERIALS

Standards to be established when information becomes available on deleterious effects.

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*From Water Quality Standards for Michigan Waters. State of Michigan Water Resources Commission. Department of Conservation, Revised June 1967.

CONCLUSIONS

On the basis of a framework-type analysis appropriate for this report, the following conclusions are drawn concerning the present and future status of the water quality of Lake Huron as it relates to fish and wildlife resources:

1. Lake Huron is not the most fertile or productive of the Great Lakes, ranking behind Lakes Erie and Michigan in this respect.

2. Lake Huron ranks second to Lake Erie in proportion of shallow areas (less than 100 feet) however, most of these areas are found in Saginaw Bay and the extreme southern portions of the open lake.

3. Except for the innermost portion of Saginaw Bay and some inshore areas of the open lake, Lake Huron has not exhibited the obvious signs of water quality degradation apparent in Lakes Michigan and Erie.

4. Although water quality is relatively high from the standpoint of fish, wildlife, and aquatic life some indications of change have developed. In the open lake there has been a slight but real increase in total dissolved solids, most of which is attributable to concentrations of chloride. Dissolved oxygen, while usually near saturation, has been reported as low as 66% of saturation in Saginaw Bay but no data are available to indicate trends in this regard. Nuisance growths of cladophora in certain inshore areas and certain species of oligochaetes indicate enriched or polluted habitat. They are dominant in the vicinity of several harbors.

5. The low human population density over much of the Lake Huron Basin in comparison with Lakes Michigan, Erie, and Ontario has resulted in relatively low inputs of pollutants from within the Basin. The condition of the open lake therefore has been and will be determined

largely by the quality of waters received from Lakes Michigan and Superior.

6. In terms of the total Lake Huron ecosystem, the water quality changes to date have probably not proceeded to a point resulting in significant adverse effects on fish and aquatic life resources. The changes that have taken place, however, should be seriously viewed as indicators that steps to slow down, and eventually halt, inputs of pollutants should be taken without delay.

7. Item 6 is especially applicable to the Saginaw Bay area. Although human population densities are relatively light in the Lake Huron Basin as a whole, most of the residents are concentrated around Saginaw Bay and the waters of the Bay receive the major portion of the Basin's pollution load. Considering the vital importance of Saginaw Bay to the Lake Huron ecosystem in general and fish and wildlife in particular, it is essential that continual surveillance of water quality conditions in the Bay be maintained and remedial steps be undertaken immediately, with emphasis on upgrading the quality of Saginaw River.

8. As a result of the 1965 Water Quality Act, Michigan has developed water quality standards to protect the fish and wildlife resources of Lake Huron. Under provisions of the Act, the Secretary of Interior has approved all but the temperature standard proposed by Michigan and it is anticipated that agreement will soon be met. A great deal has yet to be learned about adequate aquatic life criteria. Additional research may demonstrate the need for redefinition and refinement of the standards to meet fish and wildlife requirements. Moreover, it must be recognized that water quality standards are the minimum necessary to maintain various conditions of habitat quality. In view

of the rapid changes occurring in the Great Lakes ecosystem, every effort should be made to maintain the quality of those areas currently exceeding these minimum standards. It is apparent that existing water quality over most of Lake Huron is better than called for by the standards, for most if not all parameters. Unless careful research demonstrates that degradation of existing water quality to the level of the standards will not result in harmful effects upon fish and aquatic life resources, it is the position of the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife that the goal of pollution abatement in Lake Huron should be retention of the existing overall high quality of its waters. This will require improving conditions in certain local areas such as inner Saginaw Bay which are significant sources of pollution input. It will also depend heavily on present and future efforts to stop the acclerated enrichment and addition of other pollutants into Lake Michigan. Programs for maintenance of present water quality in the open waters of Lake Huron are meaningless unless the quality of incoming waters from Lake Michigan is prevented from further deterioration.

9. Because of their inherent sensitivity to subtle, long-range environmental changes, fish, wildlife, and aquatic organisms make excellent indicators of such changes, thus enabling problems to be recognized and steps taken towards their solution before they become critical in human affairs. This has not been recognized sufficiently in the past. A change of emphasis is called for in the future including acceleration of necessary research and monitoring in the fish and wildlife-aquatic organism sector of water quality.

10. Because of the special relationship of fish, wildlife, and aquatic organisms to long-term changes in water quality and the responsibility of fishery agencies to increasing man's control of aquatic living resources and their environment, it is recommended that research on long-range environmental changes be conducted by these agencies and coordinated through established institutions such as the Great Lakes Fishery Commission, with the help and cooperation of private and educational groups.

11. Lake Huron provided a relatively stable fishery in terms of total landings and species composition of the catch up to the 1930's when the effects of sea lamprey predation became apparent. Subsequently dramatic changes have occurred in the abundance of various species and total landings have undergone a progressive decline through 1967.

12. The drop in lake trout production in the late 1930's was caused by sea lamprey, although a decline from peak production at the turn of the century was probably due to heavy fishing pressure on relatively unexploited stocks. A combination of heavy exploitation by the deep-trap net fishery followed by lamprey predation also appears to have led to the decline in abundance of whitefish. The sea lamprey may also have been a factor in the decline of walleye production although there is speculation that other causes, including environmental changes in Saginaw Bay, were responsible. The almost complete disappearance of lake herring has been associated with the rapid increase in abundance of alewife following reduction of predator species, mainly lake trout, by the sea lamprey.

13. By the mid-1960's the resource base of Lake Huron was considerably changed over that of the 1930's. Instead of the previous balance of predator and prey species, the resource base was dominated by only four principal species, alewife, carp, suckers and yellow perch in Saginaw Bay and chubs and alewife in the open lake.

14. The future composition of the fishery base in Lake Huron is uncertain. It appears that alewife abundance has declined since reaching a peak in 1964 and may diminish further with acceleration of lamprey control permitting lake trout restoration and introduction of other predators such as coho salmon. There is a possibility that lake herring populations may increase as alewife competition is lessened. The status of chubs in the open lake is unclear in view of the possibility that in Lake Michigan chub stocks are in danger of collapse as the result of heavy fishing pressure and alewife competition. Carp and yellow perch will continue to account for a high proportion of the Saginaw Bay fish population.

15. The re-establishment of a balanced predator-prey relationship in Lake Huron is essential to achieving a stable and productive resource base. As previously indicated, sea lamprey control and introduction of predators will contribute to reaching such a balance. Careful monitoring of the fishery base will be necessary as these activities proceed in order to determine the nature of the changes that occur, and to indicate any possible adjustments which may be necessary in management procedures. Of all the Great Lakes, Lake Huron, and possibly Lake Superior, show the greatest potential for the return of a productive resource base within the limits of their inherent fertility and existing water quality.

16. By most criteria the commercial fishing inudstry of Lake Huron has been declining since the early 1930's. Numbers of fishermen have dropped from a modern high of 1293 in 1934 to only 303 in 1966. Total landings have declined as well while average landings per fisherman in the 1960's was slightly below 1930 levels. Value of the catch or income per fisherman has increased somewhat in money terms although in real income the value of the 1966 catch per fisherman appears to be smaller than in 1931.

17. A number of factors contributed to the present condition of the industry. A decline in abundance of the more valuable species of lake trout, lake herring, whitefish and walleye was of prime importance. Fluctuations in the resource base have increased the uncertainty associated with commercial fishing thereby limiting the desirability of investment in the fishery. Fishermen have tended to maintain relatively small enterprises and fishing has come to represent part-time employment supplementing income from other sources. Declining demand for those species currently available to the fishery, especially carp, suckers and chubs to some extent, have lowered prices and fishing income. The inability or unwillingness of fishermen to alter traditional methods of processing and marketing has led to the loss of competitiveness in the changing fishery products market.

18. Efforts to overcome many of the economic and related problems of the Lake Huron and other Great Lakes commercial fisheries have been increasing in recent years. Sanitation and handling procedures, the focus of unfavorable publicity in the past, are gradually being upgraded by

the industry with the aid of Bureau of Commercial Fisheries research efforts in technology and marketing. Promising new techniques in harvesting are currently in the field testing stages. Management agencies have begun to examine various regulatory alternatives for adjusting fishing effort and yield to prevailing biological and economic conditions in order to provide for more efficient utilization of fish stocks. Yet to be initiated on Lake Huron but recommended in this report, is the establishment of integrated harvesting, processing and marketing facilities capable of handling the low unit value species prevalent in many areas, particularly Saginaw Bay.

19. Potential demand for commercial fishery products from the Great Lakes is estimated to increase by more than four-fold by the year 2020. Even with the advances in harvesting, processing and marketing indicated in this report and development of data necessary for effective management systems, water quality is likely to become a major constraint to meeting future demands. The research and management efforts recommended for improving and maintaining water quality in Lake Huron, particularly Saginaw Bay, appear to be fully justified in view of these demands and the benefits to be derived from a stable and productive resource base.

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